

**DAHLGREN DIVISION
NAVAL SURFACE WARFARE CENTER**

Dahlgren, Virginia 22448-5100



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**SCIENCE AND TECHNOLOGY METRICS
AND OTHER THOUGHTS**

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FOREWORD

Although many Navy managers recognize that Science and Technology (S&T) programs are essential ingredients of a vigorous research and development (R&D) organization's technical capabilities, few are guided by this knowledge to take the strong actions needed to support basic science and research.

Over many fiscal years, Navy leadership has struggled with this dimension of the Navy laboratories, caught between the near-term need to fund operational forces and sustain adequate force structure and the competing need for the reliable, adequate, long-term S&T investment required to meet future challenges.

Thus, managers of S&T programs are frequently asked to show justifying measures for this investment. This has always been a challenge.

The information presented here, originated by the Dahlgren Division S&T Council, is an attempt to understand and specify a context for the metrics of S&T as applied to Navy laboratories. There is more to be done, but it is felt that the material collected and the conclusions drawn to this point should be documented now and made available to others.

Several S&T Council members participated in the various phases of this study. Mr. Larry Triola (Z08), the Dahlgren Division S&T Director, frequently let us know his opinions and made suggestions. Ms. Natalie Heffernan (W43) was also helpful with her assenting and dissenting opinions. Others who contributed their thought through the early phases of this study were Messrs. Alan Shimp (Q06), Steven Anderson (W11), and Douglas Marker (W10).

In particular, the authors wish to thank Captain Joseph McGettigan, Commander, Naval Surface Warfare Center, Dahlgren Division (NSWCDD), for enduring a two-hour session with us on this subject. Prior to the session, it was suggested that this subject would be difficult to grasp in a few charts. It proved to be more effectively understood when the full weight of researched material was confronted and viewed in the larger context of the historical evidence.

Approved by:



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CHAPTER 1

INTRODUCTION

1.1 PREFACE

The subject of Science and Technology (S&T) metrics has come up frequently during the early months of 2004; as the Naval Sea Systems Command (NAVSEA) restructuring plan has unfolded, and Navy management has tried to determine what it can do to save money to invest in recapitalizing the fleet. In this context, the question arises, “What is the value to the Navy of its investment in science and technology?” Recently, this investment has been about \$2 billion each year.

This is not a new question. History books abound in stories on this subject.

There is also another question that is asked. It is probably true that in the 21st century there are no responsible politicians who would promote the idea that S&T investment should be done away with all together. However, as recently as the last century, Hitler was quoted as saying to Max Planck, “Our national policies will not be revoked or modified, even for scientists. If the dismissal of Jewish scientists means the annihilation of contemporary German science, then we shall do without science for a few years.”

Today, the question would be, “How much S&T investment is enough?” This suggests that there is an expected return on this investment, and that the return should justify the investment. This “return” is closely related to the “value” referred to in the first question; and the “return” is sometimes stated another way, “What S&T has “transitioned” to the warfighter lately?”

To address this problem, a subgroup of the Dahlgren Division S&T Council first began discussing this in May 2004, thinking about S&T metrics, specifically the return on investment and transitions, and plotting a course to an answer. The group continued to meet about weekly through December. Each meeting, it seemed, led to new insights into this “metric beast.” The literature is filled with studies on S&T metrics, and a recent book, *The Metrics of Science and Technology* was purchased and studied. *

A common theme seemed to appear in the book and many other references; S&T is difficult to measure meaningfully. By this, it is meant that while there are many measures – like publications, patents, and awards – most of them are not helpful if a measure of the quality of the

* *The Metrics of Science and Technology*, by Eliezer Geisler, Quorum Books, 2000.

S&T is desired. Also, most of the measures do not happen during the research; but long after it is completed and made public, which is not very helpful in making management decisions.

The result was that the S&T Council decided that it was not sufficient to conclude that this is an impossible task. Navy management continues to ask the questions; and if we do not answer them, someone else will. The following sections and paragraphs describe the results of this effort.

NOTE

The reader should be aware of the fact that this document was constructed from briefing notes and minutes taken from the spontaneous interaction of S&T Council members and others who had relevant thoughts on this crucial subject. That said, this document may not appear in a polished format, but the ideas that it is meant to convey are clear.

1.2 SUMMARY

As a framework for this study, it was decided to describe the prevailing atmospheric impressions and attitudes in the Navy, as we perceive them, that makes this study necessary. Figure 1 contains the six statements that can be heard in discussions or even found in papers. The arguments and conclusions provided in this paper counter these inaccurate and misguided beliefs.

- We'll never get anything out of S&T.
- S&T is a sandbox operated for the benefit of the scientists.
- Level-of-effort programs are inefficient, stagnant, and non-productive.
- Industry will invent and develop everything we need.
- During a war S&T can be given a lower priority and placed on the back burner.
- "The DOD labs, created for the purpose of technology transition, are widely judged to be incapable."

FIGURE 1. PREVAILING ATTITUDES

To balance these prevailing impressions, the team decided to list what their beliefs were, i.e., what we assert to be true about S&T. Figure 2 presents those assertions. These assertions are supported throughout this study.

1. In-House S&T has great value to the Naval Enterprise.
2. The level of S&T required to support the Navy is independent of the number of ships or sailors. Rather it depends only on what technologies are deployed and what might be needed in the future.
3. It is clear that the Navy wants the benefits of new S&T. (...at a "reasonable" cost)
4. Low hanging S&T "fruit" is a myth.
5. The loss of institutional technical competence leads to failure.
6. S&T projects never go according to plan.

FIGURE 2. ASSERTIONS

The conclusions that we have reached were not obvious to the team at the study inception; although as we look back on them, they are fundamental to S&T activities and should have been realized long ago. Figure 3 lists the six concluding statements. The first refers to the assertions about Navy S&T that are listed in Figure 2. The second conclusion is a cautionary statement. It says that management needs to think carefully about how they define their project objectives. If the investigators are asked to summarize their projects at year's end by listing, for example, the numbers of published papers and patent applications their team has accomplished, then, to be sure, there will be papers published and patents applied for – perhaps at the expense of other actions that may have led to more useful results.

Conclusions

- Metrics can supply evidence that the basic S&T assertions in this brief are relevant.
- S&T metrics can be defined and collected in response to specific questions, but you tend to get what you choose to measure.
- The immediate ROI for Navy S&T is its contribution to the quality and development of "our people, (*who*) will determine our future success" *...or failure.
- Transitions and speed-of-transition are not significant measures of S&T performance. They may be better measures of how well the entire RDT&E acquisition process is working.
- A better measure of S&T is how well is Navy S&T addressing current and future Navy needs, and how prepared is the workforce to address those needs.
- The size of the Navy S&T budget and in-house workforce should be determined by what you want it to do. I.e. what Navy capabilities need to be enabled.

FIGURE 3. STUDY CONCLUSIONS

The third conclusion puts near-term Return on Investment (ROI) in its proper perspective. It is the workforce that benefits from hands-on S&T projects, and the Navy benefits from this experience and the resulting increased competence.

There are several reasons for the fourth conclusion. S&T provides enabling technologies, but acquisition programs must provide funds for further development and integration of the technology into their systems. S&T programs do not have this kind of money. Therefore, they cannot control transitions. Advanced Concept Technology Demonstrations (ACTDs), as an example, require the services to commit funds before the project proceeds, and thus, in this case, technologies are likely to transition. The Future Naval Capabilities (FNC) Program, as an

opposite example, does not require services to commit funds, just “promise” that they like the technology and if it works they are interested. These projects are frequently canceled, because an acquisition office loses interest.

Rather than transitions as a measure of the success or failure of an S&T project, our fifth conclusion is that a better measure might be whether the S&T workforce is addressing Navy needs and how prepared is the workforce to do the work. Transitions are a better measure of how well the entire Research, Development, Test, and Evaluation (RDT&E) acquisition process is working.

Finally, the sixth conclusion gets to the question how much S&T do we need. This should be determined by what you want the S&T workforce to do, e.g., provide enabling technology to close identified Navy Capability Gaps.

During the study, there were a few statements that kept coming up that seemed to have the character of truths. There are quite likely many more that could be listed here, but the ones that we chose to put at the very front of this presentation are listed in Figure 4. The first gets to the heart of the S&T metrics question. Of the multitude of measurements that can be applied to S&T programs, an unbiased review by knowledgeable experts, perhaps twice a year, is the one that can reveal the most about the quality and appropriateness of S&T projects. In addition to providing insight to S&T management, peer observations relayed back to the investigators can also result in improvements to research methods and procedures.

- *“Peer Review is the Sacred Cow of S&T Metrics.”*
- *“S&T outcomes are imagined and brought to reality by scientists, engineers and technologists. Yet these outcomes are applied, misapplied, and used/abused by leaders or managers in government and industry, who do not adequately understand them, their potential, and their power.”*
- *“Be careful what you measure. What you measure is what you will get.”*
- *“Technical competence requires technical tasking.”*

FIGURE 4. GEMS

The second “Gem” is related to the ultimate success of research – actual use of the S&T results by the operational Navy. It is critical that the knowledge gained during the S&T phases be carried forward to applications, to assure that the technology is appropriately used by acquisition managers and, indeed, to ensure that the acquisition managers are informed of the technology’s full potential.

Third on the list is a restatement of our second conclusion already discussed above.

The final “Gem” may be the most significant of all, and is one that is vital for a technical workforce. One of the attitudes listed in Figure 1 is “Industry will invent and develop everything

we need." Implied with this is also the need for the government workforce to manage and evaluate industry's products. Examples are numerous where this approach has failed, because the government team did not have the knowledge and experience to recognize errors and shortcomings in the Industry performance. A competent government technical workforce can only be achieved by providing significant tasking and responsibility in similar disciplines and continuing that tasking and responsibility for multiple years. This results in a technically competent workforce and continuity of the knowledge throughout the lifetime of a Navy system.

CHAPTER 2

OVERVIEW

2.1 DISCUSSION

2.1.1 Return on S&T Investment

The material that follows is a synopsis of the briefing presented to Captain Joseph McGettigan. It forms the study as seen in Figure 5. Return-on-S&T Investment and Transitions are addressed in Paragraphs 2.1.1 and 2.1.2 because of their wide interest. Paragraph 2.1.3, Assertions, follows and is covered by 24 charts found in Appendix B. This is where we attempt to demonstrate that our assertions have a basis in fact, unlike the prevailing impressions and attitudes mentioned earlier. Paragraphs 2.1.4 and 2.1.5 bring us back to the “Metrics” discussion. Paragraph 2.1.6 summarizes the Conclusions.

- 2.1.1 **Return on S&T Investment**
- 2.1.2 **Technology Transitions**
- 2.1.3 **Assertions:** These are what we believe, and attempt to demonstrate with argument, historical examples and data.
- 2.1.4 **S&T Metrics: Should be collected in response to specific questions from “evaluators.”** Several questions are proposed that might be of interest at all levels of management.
- 2.1.5 **Potential Metrics:** Metric Data collection is not a trivial enterprise.
- 2.1.6 **Conclusions**
- Appendix A: How Much Is Enough?** (Appropriate size of the S&T Workforce)
- Appendix B:** Metrics for our Value statements.
- Appendix C:** Historical Examples of Dahlgren products of S&T that have transitioned.
- Appendix D:** Examples of disruption in the scientific workforce leading to failure.

FIGURE 5. BRIEFING OUTLINE

Appendix A is where the question “How Much Is Enough?” is addressed. This will be a controversial answer, and is not adequately tested; but it suggests that a numerical estimate might indeed be feasible. The remaining appendixes are self-explanatory.

The text that follows provides some explanation for these sections although not all of the graphic material will be covered. The writers hope that you will spend time with all the material in order to appreciate that these ideas are not unique to this study. They have been stated many

times by knowledgeable people for many years. We hope having this all together in one place will increase its credibility and impact.

Return on the Navy's investment in S&T is one of the two metrics most frequently requested. Our investigation showed that ROI for S&T could not be quantified in fiscal terms in general because of the long delay between the S&T effort and when the technology is actually incorporated into a Navy system, a period that can be decades. Also, the performing Navy laboratory does not receive the financial benefit, as would be the industry case.

A note of caution is called for here. In answer to questions about what has the Navy gotten from its S&T investment, it is sometimes tempting to make a list on a view-graph and show it to a room filled with people with no connection to the history of S&T contributions. Regardless of what is on the list, someone will surely ask, and many will think, "Is that all we get for \$2 billion dollars every year?" Although we are forced to make these lists from time to time, remember the following.

CAUTION

To show examples trivializes the results of S&T investment. It is too tempting to equate a few bullets on a chart with the Navy's \$2B annual investment.

The ROI most readily described, though difficult to quantify, is the resulting state of readiness of the technical workforce to respond to recognized Capability Gaps, and to enable risk reduction throughout the acquisition process. S&T tasking certainly contributes to a prepared and experienced workforce to support in-house technical authority through continuity of core technical competencies.

Figure 6 is the summary for the ROI section of the report. Many past and current military capabilities can be linked directly to Navy investment in S&T. This investment must be continued. It is no exaggeration when we say: No Investment – No Starships!

It is widely accepted that ROI, and metrics in general, are difficult to define for S&T.

Many Military capabilities can be linked directly to S&T discoveries.

Many kinds of Risk are reduced, including the risk of technological surprise

A competent workforce is the Near-Term Navy ROI for S&T.

No Investments – No Starships!

FIGURE 6. ROI SUMMARY

One source, referring to the end of the Cold War, cited U.S. S&T capability as “an additional form of deterrent against our adversaries.” This ROI would be impossible to quantify, but certainly stands up to close scrutiny.

2.1.2 Technology Transitions

The second S&T metric frequently asked for is Technology Transitions. Within the S&T community, a transition is usually thought of as any movement between the three categories, 6.1, 6.2, or 6.3. (Particularly if the objective or metric being measured are transitions.) However, the transitions that count, the ones usually sought when this question is asked, are the cases where a technology is taken into an acquisition program that eventually ends up as a Navy capability, and this may be a transition from 6.2 or 6.3 to acquisition.

The missing ingredient in this discussion is the money. While S&T provides a “technology menu,” the acquisition programs must provide the funding for developing the technology into an operational system. The S&T community does not have this kind of money and, therefore, cannot control transitions! The missing link is the gap between the two. A “Technology Transition Manager,” focusing totally on bringing technologies to acquisition programs, would be the owner of the “Transition metric.” This position does not currently exist.

These facts are known within the Department of Defense, as evidenced by a multitude of programs specifically designed to provide funding for transition of acquisition-ready technologies. One example of this is the ACTD Program. There are many others.

We conclude that transitions are not a significant metric for S&T. A better measure is the degree to which the S&T investment is focused on current Navy needs and anticipated future needs. A corollary to this is the preparedness of the workforce to address those needs. Figure 7 summarizes our conclusions on S&T Transitions as a metric.

•ONR, ASN, and OSD recognize that bridging the “Valley of Death” between S&T and Acquisition requires programs and people dedicated to enabling Technology Transition.

S&T Metrics – Quality and Relevance
Acquisition Metrics: Budget, Schedule, and Performance
Transition Program Metrics: Successful Technology Transitions

•Transitions and speed-of-transition are not significant measures of S&T performance. They may be better measurers of how well the entire RDT&E acquisition process is working.

•A better measure of S&T is how well is Navy S&T addressing current and future Navy needs, and how prepared is the workforce to address those needs.

FIGURE 7. CONCLUSIONS ON S&T TRANSITIONS AS A METRIC

2.1.3 Assertions

With ROI and Transitions behind us, and still seeking to counter the prevailing impressions and attitudes, the team decided to list its own impressions in the form of assertions, or beliefs. Figure 8 lists our six assertions. This section of the report examines and supports the validity of these beliefs.

1. **In-House S&T has great value to the Naval Enterprise.**
2. **The level of S&T required to support the Navy is independent of the number of ships or sailors. Rather it depends only on what technologies are deployed and what might be needed in the future.**
3. **It is clear that the Navy wants the benefits of new S&T. (...at a “reasonable” cost)**
4. **Low hanging S&T “fruit” is a myth.**
5. **The loss of institutional technical competence leads to failure.**
6. **S&T projects never go according to plan.**

FIGURE 8. ASSERTIONS – WHAT WE BELIEVE

This is expanded in the list that follows.

- A. We believe that the Naval Enterprise benefits from a robust S&T program through vision to predict future naval needs; through many dimensions of risk reduction, including the risk of technological surprise.
- B. We believe that the level of S&T needed to support the Navy is independent of the number of ships and sailors, only depending on the scope of technology currently deployed and that may be needed in the future, i.e., if the fleet is reduced 10% the S&T workforce should not be correspondingly reduced. Only production levels depend on the size of the naval force. The challenge here is to appropriately predict the future needs, a task requiring knowledgeable people with vision.
- C. We believe the Navy wants (and needs) the benefits of new S&T. This is demonstrated by numerous Navy management actions of recent years, e.g., establishment of the Naval Air Systems Command (NAVAIR) Advanced Technology Investment Boards, SUBTECH, SURFTECH, CARTECH, Aegis Technology Review Board, and more. Admiral Vern Clark has said “We need a lot more Silver Foxes,” referring to a small Unmanned Aerial Vehicle (UAV) produced and delivered quickly to our special operations forces in the Persian Gulf area. *The National Military Strategy – 2004* recognizes the importance of recapitalizing and modernizing some force elements **“while investing in programs that extend US military advantages into the future.”** This desired future advantage is built on the back of patient, long-term investment in S&T.

- D. We believe that there are no “overnight” successes, i.e., low hanging S&T “fruit,” just waiting to be picked, is a myth. The Silver Fox, mentioned earlier, has been headlined as a great S&T success story; because it was delivered to Special Operations forces in only 60 days. It is never mentioned that research on UAVs that led to today’s unmanned capabilities began on the top of a Marmon automobile in 1918. The thermobaric bomb used in Afghanistan in 2002, touted as delivered in less than 6 months, was the result of over 30 years of research in basic explosive chemistry. Even the many stories of quick solutions to problems encountered by soldiers in the field were only possible because there was a trained, competent, and experienced workforce somewhere that understood the conditions and was able to formulate a solution.
- E. We believe, and it seems obvious in the Navy context, that the loss of institutional competence leads to failure. There are many stories that support this assertion. Many respected leaders have recognized this, but it continues to occur. A well-supported S&T capability is a key step on the road to maintaining this technical competence in the workforce. A recent example of loss of technical in-house competence is the Space Shuttle disaster. The leader of the Mission Management Team at Johnson Space Flight Center told reporters after the accident *"We must rely on our contractor workforce who had the systems expertise to go off and do that analysis.. We don't have the tools to do that. We don't have the knowledge to do that or the background or expertise to do that kind of thing."* For budgetary reasons, NASA had contracted out its in-house technical capability. Jim Colvard, who has written and spoken frequently on this theme, said *"Further, military preparedness is a continuous function. The retained intellectual residuals from investment in the Navy's science and technology infrastructure are available on demand to the Navy. Knowledge and experience gained through a contract operation may well be lost when the contract ends or goes to another contractor. It is appropriate within our free enterprise system that the continuous function is in-house and the discontinuous one is in industry. It takes a well-thought association of the two both to decide on and to provide material the Navy needs."* To finish this discussion, another quote from Mr. Colvard is appropriate *"Coupled with downsizing, the mergers within the defense industrial base have eliminated the competitive market in defense. This requires the Navy to be an even more technically competent buyer. Private industry is in no position to define missions, analyze requirements, and maintain the Navy's technical safety net. If the Navy loses its effective internal science and technology structure, just when it needs it most, it never will regain it, short of a catastrophic normative reset."*
- F. We believe that S&T projects never go according to plan. This is less a belief than a fact of life. Secretary of the Navy James Forrestal, in July 1943, recognized this when he stated *"Here the cause of research is close to the hearts of man. It is staffed by civilian scientists and officers of the Navy. Those men know, far better than any of us, that the results of research cannot be placed on a time schedule, that the ideas of men of genius must have time and leisure in which to flower. They know far better than any of us that the dollars invested in research in times of*

peace may mean the life of the nation when it goes to war." A current example of this is the Navy's Future Naval Capabilities Program. In this case, a very high level of initial planning occurred but the transitions – the single purpose of the FNC structure – have been no better than with the former program structure, and significant resources have been wasted in the stop/start "churn caused by frequent project terminations. There are good reasons for this: (1) it is impossible to predict when a solution will occur; (2) the Program Manager has to be convinced that the technology will solve his problem; (3) on his schedule; and (4) when he has the dollars available and the priority is there, to apply the transition dollars. Acquisition and operational managers normally focus on current issues, not what the future will need.

2.1.4 S&T Metrics

Collecting metrics for S&T can be a costly, time-consuming activity, particularly if the resulting data is not useful to someone. This is because there are a host of potential aspects that can be measured and analyzed. The book, *The Metrics of Science and Technology*¹ makes the point that metrics should be chosen only in response to specific questions from the evaluator. The presumption is that the answer is important to the evaluator. With this in mind, a set of questions were formulated, as examples that might be asked by various levels of Navy management. Figure 9 lists these questions.

<u>CNO:</u>	What is the benefit to the Navy from \$2B annual TOA in Navy S&T accounts?
	What is the benefit to the Navy from the government and contractor workyears devoted to management, identification, or development of S&T products?
<u>CNR:</u>	How well is my S&T money addressing Navy Technical Needs?
	What is the quality of Navy S&T compared to all other S&T?
<u>NAVSEA:</u>	How do S&T people and funding support the NAVSEA Technical Authority responsibilities?
<u>NSWC:</u>	How does S&T help meet PAD current and future responsibilities?
<u>DD CO:</u>	Are my S&T demographics in line with PAD and Technical Pyramid needs? What is the health of the Dahlgren Division S&T program?
<u>DD S&T Director:</u>	Do my S&T projects address PAD and other DoD needs?

FIGURE 9. POSSIBLE EVALUATOR QUESTIONS

¹ *The Metrics of Science and Technology*, by Eliezer Geisler, Quorum Books, 2000.

The nature of the questions changes as you get further from the actual performing investigators. The Chief of Naval Operations (CNO) wants to know what benefit the Navy is getting from their investment. The S&T Director at Dahlgren Division, who manages the Division investments, is more concerned with the quality and appropriateness of his project selections. As an example exercise, the Division Commander's question "What is the health of the Dahlgren Division S&T program?" was taken. Figure 8 lists some program measurers that might be gathered to answer this question.

The color codes help to categorize these 16 types of metrics shown in Figure 10. **Blue** indicates the ones that are actually manageable, under the control of management. That is, management can take actions to adjust these numbers in the short term. Only four fit this category. The **Green** color indicates those that can be readily counted. For example, the number of publications resulting from the S&T projects can be gathered at years end, or more frequently if desired. It is less possible to require papers submitted for publication since it is not possible to schedule publishable results. The third color, **Red**, is the problematic group of measures. Transitions may take decades to achieve, and later yet, the ROI may not be realized until the technology is actually deployed.

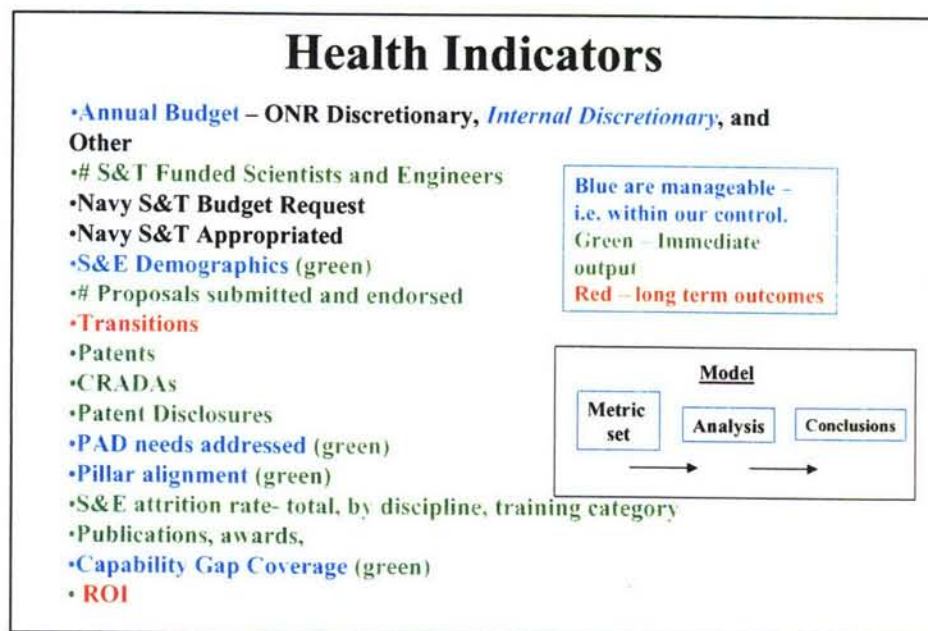


FIGURE 10. S&T HEALTH METRICS

Nonetheless, there are measures that can be gathered that give an evaluator a sense of an S&T program's value. Mr. Fountain² remarks "*Presently there is no widely accepted way for the federal government in conjunction with the scientific community to make priority decisions about the allocation of resources in and across scientific disciplines. While metrics*

² • "Transforming Defense Basic Research Strategy", Augustus W. Fountain, III, from *Parameters*, Winter 2004-05, Vol. XXXIV, no 4. pages 40 to 54. *Parameters* is the US Army War College Quarterly. Page 45

such as the number and quality of peer-reviewed publications, citations, graduate students, research awards, and the level of external funding are indicators of a vibrant research program, they do not necessarily show how the needs of the warfighter are being met.” We can help somewhat in this by gathering data on the three blue metrics: Product Area Directorate (PAD) Needs Addressed, Pillar Alignment, and Capability Gap Coverage. However, only at the transition stage can the resulting technologies be evaluated (ROI) for their significance to the warfighter. Quality assessment during the S&T investigation phase must be left to peers: “*Peer Review is the Sacred Cow of S&T Metrics*” (Geisler).

2.1.5 Potential Metrics

This section of the material is a listing of possible metrics associated with each of the Value Statements discussed under Assertion 1 of Figure 8 in Section 2.1.3. It is shown in Figure 11. This demonstrates again that there are many ways to measure S&T, but wariness is called for in their selection.

<u>Value Statements</u>
1. In-house S&T enables the recruiting, training, and retention of a technically competent scientific and engineering workforce.
2. Real-time connections between S&T Workforce and acquisition programs enables focused technology for the warfighters.
3. The in-house workforce is highly responsive because of it's ability to innovate and it's knowledge of Navy systems.
4. Long term continuity of experience is essential and can be assured because of flexibility – due to the proximity of technical acquisition responsibilities - in the ability to provide continued support for the technical experts.
5. The S&T trained workforce, by its nature, is agile and adaptive, bringing vision and innovation to future Naval capabilities.
6. Practical applications of new and emerging science and technologies can be focused to support Fleet needs.
7. The in-house S&T- trained workforce is able to anticipate and provide the capabilities to stay ahead of future threats; and reduce many dimensions of risk.

FIGURE 11. VALUE STATEMENTS FOR ASSERTION #1 – IN-HOUSE S&T HAS GREAT VALUE TO THE NAVAL ENTERPRISE

2.1.6 Study Conclusions

Our conclusions are listed in Figure 12. They should be supported by the material developed during this study.

- Metrics can supply evidence that the basic S&T assertions in this brief are relevant.
- S&T metrics can be defined and collected in response to specific questions, but you tend to get what you choose to measure.
- The immediate ROI for Navy S&T is its contribution to the quality and development of “our people, (*who*) will determine our future success”*...or failure.
- Transitions and speed-of-transition are not significant measures of S&T performance. They may be better measures of how well the entire RDT&E acquisition process is working.
- A better measure of S&T is how well is Navy S&T addressing current and future Navy needs, and how prepared is the workforce to address those needs.
- The size of the Navy S&T budget and in-house workforce should be determined by what you want it to do, i.e. what Navy capabilities need to be enabled.

FIGURE 12. CONCLUSIONS

2.2 THE REMAINING QUESTION

Now that we have discussed ROI, and the nature of S&T Transitions, and have suggested that there are many “metrics” that can be conceived and tracked – if one is patient enough – there is still one burning question: “*How Much is Enough?*” From the “Big Navy” perspective, is it possible to estimate – to a few significant figures – the annual S&T investment that would adequately provide a secure feeling that we were ahead of any potential adversary, now and particularly in the future, and that would assure that we produce Navy systems, particularly the big long-lead items, that are not obsolete, relate to the threats to be encountered, even before they are deployed.

Over the years, there have been many observers who realize the dangers a nation faces if the annual investment in S&T is significantly disrupted. This is not obvious to many people, including some of our political and military leaders. A few examples that follow will illustrate this point:

- A. **During WWI, the American Chemical Society offered to supply chemists to the Army. The Army replied, “*Thank you very much, but we already have a chemist.*”***
- B. **“...when (Robert) Millikan (1930s) offered the services of the National Research Council to a conference of generals, the assistant chief of staff for supply implied that there was little need for scientists to dream up new weapons or to suggest ways to use scientific breakthroughs— those matters would be handled internally by the armed services.” (Laboratory Warriors – pg 26)**
- C. **“Our national policies will not be revoked or modified, even for scientists. If the dismissal of Jewish scientists means the annihilation of contemporary German science, then we shall do without science for a few years.” (Jung, 43). (Hitler to Max Planck)**

- D. *"The DoD should be more ruthless about cutting defense labs. There is little these labs offer that the private sector can't match. While some capabilities are unique to the [DoD], these are far fewer than their proponents will admit, and many hark back to technologies that have long since been bypassed in the private sector...the need for a large defense laboratory structure is simply indefensible..."* Source: Dov Zakheim, CEO, SPC International, 17 Jun 97 HASC testimony.
- E. A quote from *Laboratory Warriors*, page 63: *"Upon taking office (1934), President Roosevelt had created a Scientific Advisory Board under Karl T. Compton, the Princeton physicist who had become president of MIT, but that board had not been able to do much. It identified such glaring problems as the Navy's inadequate salaries for civilian scientists, which had forced the navy to allow civilian employees to patent their own inventions rather than deed them to the government, and which had practically halted the free cooperation between the navy and commercial organizations like Bell labs. The Board recommended significant increases in government-supported military research: currently less than 2% of the service's annual budgets were being spent of R&D. Roosevelt brushed off that idea, believing that during the depression any new money must be spent on social-relief measures."*

On the other side:

- A. In 1940, President Roosevelt was persuaded by Vannevar Bush to establish a National Defense Research Committee to improve American scientific preparedness for war. Bush's philosophy for the new organization was his belief that *"know-how"* could be *"acquired only by constant research"* and that the quantity of research was as important as the quality in obtaining quick answers to questions about such things as the design of new aircraft. **
- B. *"Historical evidence proves there are serious consequences when technical capability is lost or technical advice ignored."* (Colvard)
- C. President Harry Truman: *"No aspect of military preparedness is more important than scientific research."*

For these reasons, a logical methodology for establishing the optimum level of S&T effort might help convince policy makers that they should continue to support a healthy, robust, and competent Navy S&T workforce. In 1998, a Defense Science Board (DSB) Task Force on "Defense S&T Base for the 21st Century" was asked to look into the next century and recommend *"How much DoD science and technology (6.1, 6.2, and 6.3) is needed to maintain continued U.S. supremacy considering U.S. and global civil technology?"* They surveyed industry to find out what their investment was and how corporate board rooms decided how much to invest. They reported that *"No formula was discovered for establishing the optimum level of DoD investment in science and technology, but the most successful industries invest*

about 15% of sales in research and development with about 3.5% of sales invested in research (equivalent to the DoD S&T program)."

This gives us two bounds for the S&T activity.: (1) Roosevelt's Scientific Advisory Board said 2% was not enough, while (2) the 1998 DSB Task Force said 3.5% should be adequate. In terms of the Navy 2003 Task Obligation Authority (TOA), during which the Navy work force was 181,902 civilians, these percentages would suggest levels-of-effort of

2.0% = 3638 people: Not enough

3.5% = 6367 people: Adequate

We do not have the "real" number for the Navy 2003 S&T workforce, but Office of Naval Research (ONR) reports that there are about 4000 Navy people working S&T at least half time, a number that includes Navy investigators working under tasking from outside the Navy. This number could be converted into a level-of-effort for comparison purposes, but it is clear that it is on the low side of our range.

An Algorithm: As an exercise, we tried to calculate the level-of-effort needed to address the widely accepted Capability Gaps produced by N7. These Capability Gaps should represent a "best guess" at what the current Navy thinks it needs, but should be adjusted to add in some "future needs" that result from a more visionary look at the future. Our approach is to estimate the level-of-effort needed to address fully this accepted set of Navy Needs. This would represent a guess at how much is enough, and could be compared to the boundaries discussed above.

Therefore, our S&T workforce estimate will be based on what we want this workforce to do, i.e., close the Navy Capability Gaps.

An additional workforce dimension can be added related to the Navy Technical Holders (or WHs). Each of these is supported by a pyramid of "experts," some of whom will be part of the S&T workforce. (A partial survey of the Warrant Holders confirmed that they believe they need this S&T component of their support pyramids.) Figure 13 is the resulting algorithm.

- | |
|--|
| <p>1. S&T Level of Effort :</p> $N_{\text{people}} = (1 + P_{\text{over}}) * N_{\text{s\&t}}$ $N_{\text{s\&t}} = N_{\text{p/a}} * N_{\text{a}} * N_{\text{g}} * (N_{\text{s}} + N_{\text{e}})$ <p>2. NAVSEA Pyramid Support :</p> $N_{\text{whp}} = N_{\text{wh}} * N_{\text{avgwhp}} * P_{\text{ps\&t}} * (1 - P_{\text{overlap}})$ <p>3. Infrastructure Cost:</p> $C_{\text{infra}} = n * (N_{\text{people}} + N_{\text{whp}}) * WY$ <p>4. Total = N total = 1 + 2 is number of people.</p> <p>Cost is 3 + cost of people.</p> |
|--|

FIGURE 13. S&T WORKFORCE ESTIMATION ALGORITHM

Notice that a cost has been included to cover infrastructure. It should correctly be a percentage of the existing cost of laboratories and equipment, but since we do not have this number we simply equated it to a fraction, n , of the number of S&T people, priced at an average Work Year (WY) cost.

This algorithm is fully derived in Appendix A of this paper. A few sample cases are shown in Table 1. Case #1 says that for 100 gaps, representing 600 projects, and assuming 10% overhead, 2640 S&T work years are needed, only about 1.45% of the Navy TOA workforce. The case 1A, for another set of parameter values, brings us up to 3.46%. (*Note: this calculation needs to be more carefully thought through for appropriate parameter values.*) Some may consider the first estimate conservative, where the second is more in line with the DSB recommendation.

TABLE 1. SAMPLE WORKFORCE ESTIMATION CASES

<u>Parameters</u>	<u>Case 1</u>	<u>Case 1A</u>	<u>Case 2</u>	<u>Case 3</u>	<u>Case 4</u>	<u>Case 5</u>
Ng	100	100	100	75	100	75
Na	2	3	2	2	2	2
Np/a	3	4	3	3	3	3
Nproj	600	1200	600	450	600	450
Ns	2	3	2	2	2	2
Ne	2	2	3	2	2	3
Ns&t	2400	6000	3000	1800	2400	2250
Pover	0.1	0.05	0.1	0.1	0.1	0.1
n	1	1	1	1	1	1
WY	150,000	160,000	150,000	150,000	150,000	150,000
P%infra	0.1	0.3	0.1	0.1	0.1	0.1
Cpeople	\$711,630,000	\$1,209,600,000	\$810,630,000	\$612,630,000	\$756,720,000	\$731,970,000
Cinfra	\$71,163,000	\$362,880,000	\$81,063,000	\$61,263,000	\$75,672,000	\$73,197,000
Ctotal	\$782,793,000	\$1,572,480,000	\$891,693,000	\$673,893,000	\$832,392,000	\$805,167,000
Nwh	167	100	167	167	167	167
Navgwhp	60	60	60	60	60	60
Pps&t	0.3	0.3	0.3	0.3	0.3	0.3
Poverlap	0.3	0.3	0.3	0.3	0.2	0.2
Nwhp	2104	1260	2104	2104	2405	2405
Npeople	2640	6300	3300	1980	2640	2475
*percentage	1.45%	3.46%	1.81%	1.09%	1.45%	1.36%
Ntotal	4744	7560	5404	4084	5045	4880
*percentage	2.61%	4.16%	2.97%	2.25%	2.77%	2.68%

*Percentages are of the FY 03 Navy civilian workforce of 181,902

Another example can be done for the Navy In-House Laboratory Independent Research (ILIR) Program. We have data for 1993 to 2001 for comparison. Using the Number of projects funded each year, Figure 14 shows results for ILIR.

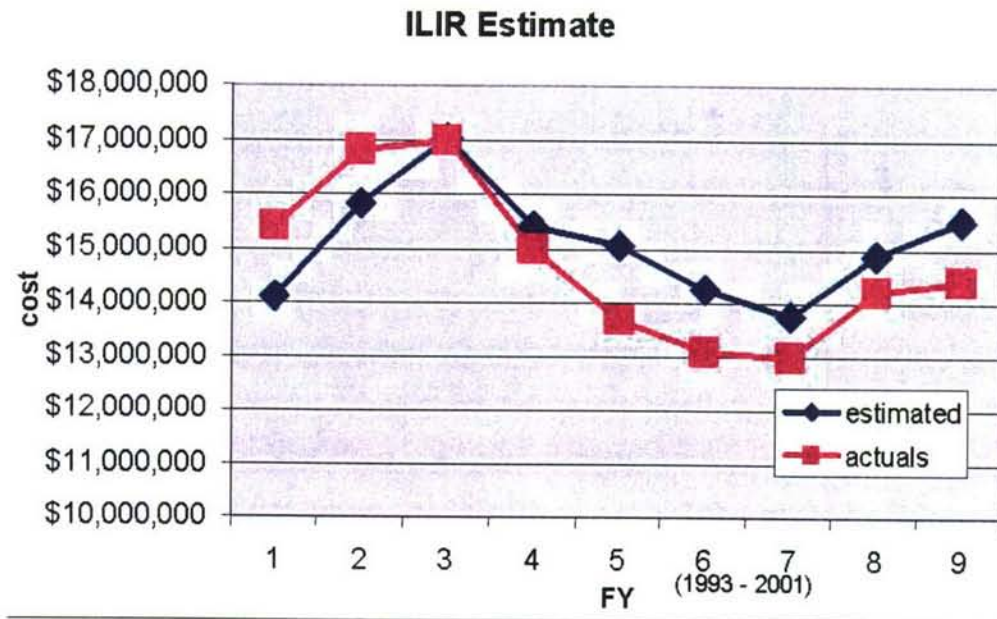


FIGURE 14. NAVY ILIR ESTIMATE

Clearly, the parameters can be adjusted to make the match nearly perfect; but the point is that the estimate is pretty good for this level of estimation.

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APPENDIX A

HOW MUCH OF A NAVY S&T EFFORT DO WE NEED?

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This is the burning question that seems to be forming in Navy leadership's mind. Money is scarce. The Navy needs big things – like ships. These are billion-dollar items, and the Navy S&T budget stands out as about \$2 billion, and not much return on this investment in the short term (some would say).

The “short term” is the new way to say not much is being produced that our Navy can use in the next year or so. So, if our S&T efforts cannot help our sailors and marines in the current war, then why do we need it at all?

But, suppose we all agree that “zero” is not the right answer to our question. This is probably a statement that almost everyone will sigh up to, as long as their agreement goes no further than this. The critical question then becomes: “If not “zero”, then how much is enough?”

This is the question we want to try to answer.

When we say “S&T effort,” we mean a group of people, with an appropriate laboratory infrastructure, working on ways to do things and build things that we currently do not know how to do. Sometimes it is even about discovering things that you did not know could be discovered, and did not know you needed – the unknown unknown. This is a critical thought to keep in mind as we proceed along our path to an answer.

We begin with the notion that the S&T team is trying to solve some problems, or provide the enablers that lead to the solutions. One way to scope out the magnitude of effort needed is to know what the navy believes is its biggest needs, or gaps in our desired capabilities. Capabilities are much more productive to think about than technologies. It is often a pitfall of these conversations with scientists and engineers, because this group naturally wants to leap into the solution (i.e., the technologies) before the problem is fully defined (the needed capability). Another way to think about this is to define “What” we need before we discuss “How” to get there .

A.1 CAPABILITY GAPS

The Navy is now focused on Capability Gaps. N07 has a process, Naval Capability Development Process (NCDP), that it uses to sort through various need statements before

agreeing to a key group of capabilities for the S&T community to work on. ONR is focused on FNC, each of which has underlying enabling capabilities, and are usually related closely to the N07 Capability Gaps. Joint Forces Command (JFCOM) last year produced a set of "S&T Capability Issues" (7 October 2003) that are important from their perspective. There are probably more.

Thus, if we accept these lists, that have high-level Navy approval, we can establish the S&T objectives and, hopefully, avoid controversy in this initial step toward answering our question.

Table A-1 shows the number of issues – Capability Gaps – defined by JFCOM, N07 (NCDP), and ONR's FNC Integrated Process Teams (IPTs) (POM-06).

TABLE A-1. DEFINED CAPABILITY GAPS

<u>Summary</u>	<u>issues</u>	<u>tasks (Ecs or sub tasks)</u>
JFCOM	36	75 – do not match to other two
NDCP	26	* – seven unique from POM 06
POM-06	25	74 – six issues unique from NCDP

If we single count the repeating issues in NCDP and POM-06, we have 19 on both lists and 7 and 6 unique, respectively, leading to 32 Capability Gaps. Just about all of the JFCOM issues are distinct from the other two. So, across these three sources, we count 68 separate issues.

The JFCOM and POM-06 lists also provide under the big issues, several subtasks that look like Capability Gaps. NCDP does not define their gaps below that level, but JFCOM and POM-06 lists go another level of definition down, showing 75 and 74 subtasks, respectively. This equates to 149 subtasks for the 68 issues. Therefore, our first parameter is as follows:

Ng = number of Naval capability gaps (A-1)

Without further defining the sub-gaps here, let it be said that they frequently read as very significant problems, not the kind of thing that you would look into the eyes of an eager young scientist and tell him to go off and solve this problem alone. (e.g., Global Strike)

A.2 THE EFFORT

Because these Capability Gaps tend to be significant, it seems reasonable that there might be more than a single approach, remembering that these goals have never been reached before; and there might be reason to believe that the state-of-the-art is not yet sufficiently mature to support a solution. Also, there is frequently more than one technology direction for a given problem, leading to different groups of experts. Our second parameter now becomes the following:

Na = number of approaches per gap (A-2)

Each approach may conservatively result in several projects in a formula defined as follows:

Np/a = Number of projects for each approach (A-3)

A.3 NUMBER OF ANNUAL PROJECTS

We can now estimate the number of projects each year for this group of Capability Gaps by using the following formula:

Nproj = Np/a * Na * Ng (A-4)

A.4 STAFFING

These projects are staffed with scientists and engineers, giving us two more parameters as shown in the following formulation:

Ns = number of scientists per project (A-5)

Ne = number of engineers per project (A-6)

Thus, the scientists and engineer staffing level for these **Ng** Capability Gaps is as follows:

Ns&t = Nproj * (Ns + Ne)
= Np/a * Na * Ng * (Ns + Ne) (A-7)

And, to be complete, there will be an overhead staff, secretaries, and maybe technicians, of some percentage of this total:

Pover = fractional overhead (A-8)

A.5 S&T STAFFING COUNT

The number of people performing the tasks associated with **Ng** Capability Gaps is as follows:

Npeople = (1+Pover)* Np/a * Na * Ng * (Ns + Ne) (A-9)

A.6 WHAT DO WE HAVE?

We now have six parameters that we can vary to compute the number of people needed to work on the projects represented by **Ng** Capability Gaps. However, there are some underlying realities to consider:

1. All projects are treated the same. Basic science (6.1) projects look just like capability demonstration (6.3) projects, which we intuitively know isn't the case. But, this calculation could be divided into three parts to allow the average parameters to be different.
2. The gap count probably doesn't adequately cover projects not specifically associated with a gap, particularly projects looking toward the future, beyond the "gap epic" that we "know" about. That is, the unknown unknowns that might someday reveal themselves during a research experiment or test are not captured if we insist on rationalizing the proposed "gaps" in today's environment. The gap count, as approved by N07 or JFCOM is going to be conservative.
 - (a) Also, this count should include the significant sub-gaps in the gap definitions because experience shows that the "big gap" is usually too large. Ex.-Global Strike is a "big gap," but it has several challenges listed within its definition that should be used in the gap count.
3. The number of approaches identified for each gap will certainly depend on the scope of the specific gap, some being a lot broader than others. For example, a gap that requires sensing something and interpreting what is observed could result in separate approaches for separate types of sensors, of which there could be many; and then, the interpreting part could be separate, requiring totally different kinds of analysis, computing, hardware, staffing, etc., to cover the possibilities. So, **Na** could be 2 or 10. Each approach might result in several projects. Thus, **Np/a** could be 2 or 10. This algorithm assumes an average across all possible cases.
4. The overhead adjustment will probably be a small fraction, say 5 to 10 percent, e.g., **Pover** = 0.05. In some cases, this might be used to account for other types of people than secretaries and an occasional manager, e.g., range technicians, or craft-people to build special test apparatus. But, for this algorithm, a single number will be used, probably between 5% and 10 %.
5. Again, the scientist and engineer staffing will vary widely from project to project. The parameter values for **Ns** and **Ne** should be carefully discussed and understood by all who use this algorithm.
6. Validation of this algorithm can never be done precisely. But, it should be attempted. Later in this paper we will come back to this.

A.7 COST OF S&T

We now have a number for the workforce directly performing the S&T projects associated with a set of approved Capability Gaps. The cost of this effort is this people cost and the annual cost of the associated laboratory infrastructure. The existing infrastructure is considered a one-time cost, which can be estimated, but will not be a focus of this paper, except that the annual upkeep and improvements can be considered as some fraction of the sunk cost.

If the sunk cost is known, then the infrastructure maintenance might be taken to be the following:

$$C_{\text{infra}} = (P\%_{\text{infra}}) * (\text{sunk cost}) \quad (\text{A-10})$$

where

$$P\%_{\text{infra}} < 1 \quad (\text{A-11})$$

Another way, perhaps more conservative, is to consider the infrastructure sunk cost to be a multiple of the personnel cost.

$$C_{\text{infra}} = n * (N_{\text{people}} + N_{\text{whp}}) * WY \quad (\text{A-12})$$

where

$$n \geq 1 \quad (\text{A-13})$$

and

$$WY = \text{a consolidated work year rate.} \quad (\text{A-14})$$

and people cost is as follows:

$$C_{\text{people}} = N_{\text{people}} * WY \quad (\text{A-15})$$

Then, the total annual cost is figured as follows:

$$\begin{aligned} C_{\text{total}} &= \text{infrastructure} + \text{people} \\ &= C_{\text{infra}} + C_{\text{people}} \end{aligned} \quad (\text{A-16})$$

A.8 ONE MORE DIMENSION

There is one more consideration for the S&T workforce count that might be significant. NAVSEA has a system of technical experts acting as Warrant Holders in many specific

engineering areas. These Warrant Holders are supported by an identified underlying cadre of experts to whom the Warrant Holder can go to seek advice when issues arise. It is viewed as critical that this cadre, referred to as the technical pyramid with the Warrant Holder at the top (Figure A-1), be constantly refreshed in order to ensure technical continuity through the life of the technical area. It is believed that the S&T workforce that we are discussing provides an important dimension to this pyramid.

It is known that there are many cases where S&T people move on to acquisition programs with the results of the technology efforts. Also, S&T experience early in a career can be found across the warfare centers in development groups and various levels of management. This is where two of our assertions enter this discussion:

- A. **The loss of institutional technical competence leads to failure.**
- B. **In-House S&T has great value to the Navy as an institution.**

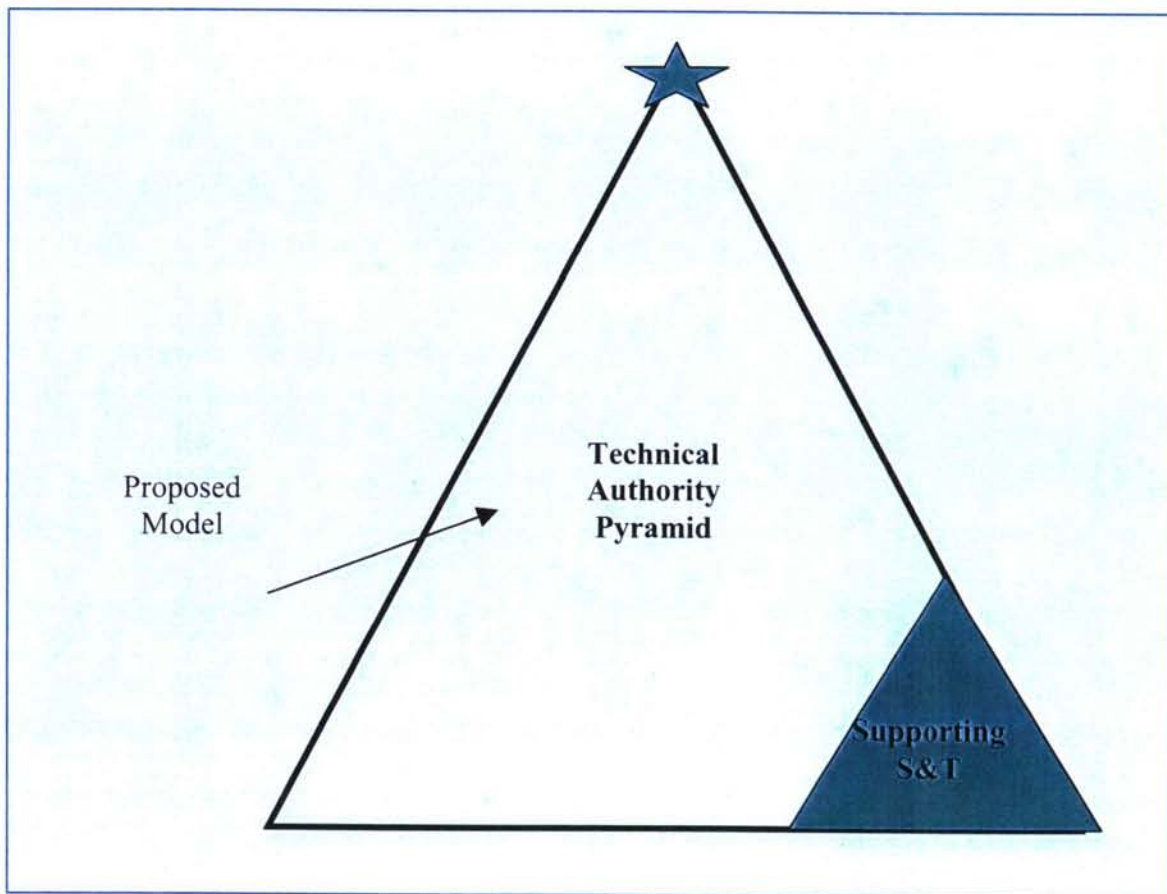


FIGURE A-1. TECHNICAL AUTHORITY PYRAMID

The point here is that there is a component to the S&T workforce that directly supports the technical pyramids. Any decision to reduce the S&T workforce should consider the

consequences to maintaining a healthy technical pyramid supporting the technical Warrant Holders.

The question now is how to factor this into the answer to the question “**How much S&T is enough?**” One approach is to survey the Warrant Holders and ask them how they view this component of their supporting pyramid. What do they think is an adequate level of this kind of expertise? Since there are 167 Warrant Holders in NAVSEA, and some equivalent numbers in the other system commands, this survey would represent a substantial data collection effort. Maybe by estimating an average across all of these pyramids we can begin to see just how many scientists and engineers this might represent. If

$$N_{wh} = \text{number of Warrant Holders} \quad (A-17)$$

and

$$N_{avgwhp} = \text{average number of S\&T trained people supporting each Warrant Holder} \quad (A-18)$$

then the S&T workforce component supporting Warrant Holders is as follows:

$$N_{whp} = N_{wh} * N_{avgwhp} * P_{ps\&t} \quad (A-19)$$

where $P_{ps\&t}$ is the fraction of the pyramid that is S&T trained.

This, however, needs to be adjusted for those overlapping between the S&T projects and the technical pyramids.

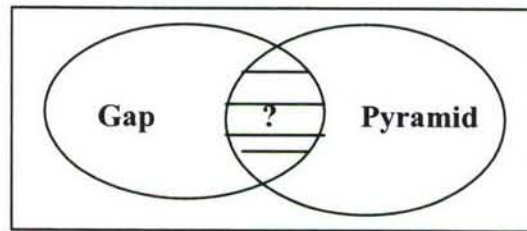


FIGURE A-2. OVERLAP

If we estimate an “average” percentage of overlap, $P_{overlap}$, then we can adjust our number accordingly:

$$N_{whp} = N_{wh} * N_{avgwhp} * P_{ps\&t} * (1 - P_{overlap}) \quad (A-20)$$

If we include these people in our count, the total S&T workforce that must be maintained is formulated as follows:

$$N_{total} = N_{people} + N_{whp} \quad (A-21)$$

A.9 VALIDATION

The validation of an algorithm like this is critical to its ultimate credibility. This cannot be done with great precision by the nature of the question. There will always be controversy over the selection of parameters; how to count this or that; just what the maximums or minimums might be; or indeed, whether our question is even answerable. But there are some confidence building approaches that may help.

1. A quote from "Laboratory Warriors", page 63:
 "Upon taking office(1934), President Roosevelt had created a Scientific Advisory Board under Karl T. Compton, the Princeton physicist who had become president of MIT, but that board had not been able to do much. It identified such glaring problems as the Navy's inadequate salaries for civilian scientists, which had forced the navy to allow civilian employees to patent their own inventions rather than deed then to the government, and which had practically halted the free cooperation between the navy and commercial organizations like Bell labs. The Board recommended significant increases in government-supported military research: currently less than **2%** of the service's annual budgets were being spent of R&D. Roosevelt brushed off that idea, believing that during the depression any new money must be spent on social-relief measures."
2. A.DSB 2001 Summer Study says **3% of TOA** should be S&T. I would take this to be an optimum number.
 - (a) In FY=02, Navy civilian workforce was 181,902. Then the S&T workforce should have been $0.03 \times 181,902 = 5457$ people.
 - (b) A previous DSB study, 1998, stated: "No formula was discovered for establishing the optimum level of DOD investment in science and technology, but the most successful industries invest about 15% of sales in research and development with about 3.5% of sales invested in research (equivalent to the DOD S&T program)."
3. Another "validation" approach would be to agree on an appropriate in-house/out-house split for Navy S&T TOA. Let's say 40/60 is "good" and reasonable in-house/out-house distribution. **Then, using your \$150k per man year, my number of 3% of civilian workforce, yields $150k \times 5457 \text{ people} = \$818.6M$. That is $818.6/1714.3$ (ONR S&T TOA) = 44% for in-house support.**
4. The "NLCCG Community DON S&T" Chart – about number 8 in the brief, suggests that ONR pays for the salaries of approximately 2375 Department of the Navy (DON) employees. I arrived at this by totaling the in-house DON S&T for Warfare Centers and the Naval Research Laboratory (NRL) -\$474.7M or \$475M and using an approximate man-year estimate of \$200k to account for travel, purchases of equipment and supplies, etc. The 2375 is an upper limit. In FY03, Navy TOA was \$111B, Navy S&T was approximately \$2B or 1.8% of TOA. Thus, if ONR funded

it's "fair share" of S&T costs, they would have paid for approximately 3280 salaries. (Robin Staton)

5. The Public Sector Innovation Working Group recommended 1% of GDP for the Department of Defense, National Science Foundation, and Department of Energy. In 2004, GDP was \$11,733.5B.
6. "To answer your question, "what the ONR S&T workforce number is?" based on the attached report we have been saying that **about 4000 people are funded at 50% or more from an S&T PE.**" (Ernest L. McDuffie, Ph.D., Deputy Director N-STAR)

One of our team members gave this clarification: (Bob Kavetski gave a very good brief at the B department offsite today. He used the "4000 half time or more" number and I asked him about it. That number is their estimate of the TOTAL S&T workforce in the WCs + NRL, funded from ALL S&T sources. He used the chart from NLCCG (865M ONR S&T to NLCCG, 475M spent in-house). I pointed out that at 200k per manyear, that is about 2375 manyears. He agrees that the ONR-funded workforce is much less than the 4000 number. He says that NRL quotes that \$1M in-house buys six manyears. Using that estimate, if the 475M was spent totally on salary for S&Es doing S&T work, ONR would be paying for 2850 manyears. Apparently, his estimate of 4000 relies on the total NLCCG Community S&T funding of \$1428M, of which the chart says \$584.8M is spent in-house. If the 584.8M was totally for S&T salaries, using the NRL estimate (\$167k/manyear), you get 3509 manyears of S&T expended in the NLCCG. (Robin Staton)

These six "observations" provide a ballpark sense of what the S&T workforce is today and what it perhaps should be if you agree with the DSB. It should be remembered that our algorithm provides a level-of-effort estimate, which is different from the people count that Dr. McDuffie refers to in item 6 in the above listing. Note that references for these studies are given in reference listing.

A.10 CONTRARY OPINION

Here is a contrary opinion on this approach that points out the difficulties of trying to forge an algorithm to compute the size of the S&T workforce.

"You have proposed an incredibly complex problem. Some considerations:

We do not have a science of complexity. We have no idea what the fundamental parameters are that define and control complex systems. Inventing technology and adapting it to national defense is a quintessentially complex problem and complex system. How do we model the individual components? How do we know what to define as the individual "atoms" of this complex system? What are the processes? How many are there? Which ones are more important than others? How many people does it take to execute a single process in the set of processes that exist to discover, identify, prove concept, inject into acquisition and support?

Which brings up the issues of supporting the pyramids. Not only must we know how many, but the complexity of answering the mail for each one. Is a pyramid going to require a single person to keep smart on pumps or will we require an entire lab system to keep smart on signal processing and sensor technology alternatives? Will a single POC for "questions processing" suffice for several simple pyramids or will a single leader with many supporting infrastructure folks be required for a single but complex pyramid?

One cannot just look at the number of "gaps" or problems to be addressed but also the relationship among gaps, the complexity of a gap, the severity of a gap, the expansiveness and pervasiveness of a gap. Methods for cross-pollination, cross-discipline, cross-mission solution generation must be researched.

Complex systems have subsets, which have subsets, which may also be complex. There are -goes-intos and goes-out-ofs; there are internal processes, data and resource streams, products/subproducts, feedbacks, interconnections and interactions both positive and negative, and some delineate-able border to the system. However, for national defense (or even the Navy) these borders are fuzzy. The systems and subsystems keep modifying as do the processes. I contend that we can develop a science of complex systems and define the navy/DOD S&T process from discovery to delivery to Life cycle support to decommission. But, we DO NOT have that knowledge today. Attempts to mathematically derive a number of scientist and engineers that must be involved in the process (individual S&T actors) without that science in place is a speculation, not a numerical solution.

Model the problem sets, model the solution processes in an abstracted idealized manner, model cross-links for synergy, model resource consumption. Then we might be able to develop the PARAMETERS that go into your calculation. The algorithms are yet another story. I'm sure that Balisle and some others would like the solution curve to be a monotonically decreasing curve or perhaps even a step function that rises rapidly and flattens. BUT, the answer set is much more likely to generate an exponential curve that shows the law of INCREASING returns without a maximum ----only a minimum below which nothing gets done so why bother. Then the question becomes how much above the minimum should we invest to do the "right" level. But, the "right" level is meaningless except in terms of national survival and cost of our blood and treasure. What metric says we are doing "right" "?????" (Larry Triola)

It is true. This is not an easy estimate to make. But, we know that these estimates are made everyday without *any* data; and they will continue to be made. So, we want to see if this approach, identifying the objectives – the Capability Gaps – and approaching the question of staffing needed to close the gaps, is helpful in defining an appropriate level of S&T for the Navy. There is historical precedent that S&T funding is determined often on political grounds (as President Roosevelt's example shows) or on very short term expectations, i.e., if we cannot schedule breakthroughs and provide innovation to the fleet in a year or so, then the money is better used elsewhere. Even today it is still heard that the money spent on S&T cannot produce anything to support "*this*" war, so we should spend it on something that can – like bullets and tanks.

A.11 WHAT ARE THE CAPABILITY GAPS TODAY?

Below are the Unclassified Naval Gaps from the POM 06 process, as provided from N07. Also, see Table A-2 for a list of POM-06 prioritized gaps and enabling capabilities. Table A-3 is an example of personnel versus cost calculations.

1. Urban/Asymmetric Operations
 - (a) Improvised Explosive Devices
 - (b) Hostile Fire Detection and Response
 - (c) Position-Location-Information in GPS Denied Environment
 - (d) Transparent Urban Structures
 - (e) Fortified Position Security
 - (f) Modular Scalable Weapons
 - (g) Defense of Harbor and Near-Shore Naval Infrastructure Against
 - (h) Asymmetric Threats.
2. Organic Mine Counter Measures-All Aspects
3. Knowledge Superiority and Assurance
 - (a) Improved Cooperating/Non-Cooperating Target Situational Awareness
 - (b) Combat ID-All Aspects
 - (c) Enhanced Warfighter Use of ISR
 - (d) Dynamic Target Engagement & Enhanced Sensors
 - (e) Unmanned Combat Air Vehicle
 - (f) Data Fusion to Identify Adversary Intent
 - (g) Optimal Mix of Large Manned / Unmanned Sensor Networks
 - (h) Secure Collaboration / Trusted Processing
 - (i) Advanced Communications
 - (j) Global Information Grid (GIG) Compliant Networking
 - (k) Next-Generation Command, Control & Decision Support Services
4. Expeditionary Logistics
 - (a) Sea Base Integrated Operations
 - (b) Sea Base Mobility and Interface
 - (c) Sea Base Collaborative Command and Control
5. Littoral Anti-Submarine Warfare
 - (a) Surveillance, Search, and Localization Sensor System Performance
 - (b) Torpedo Improvements
 - (c) Smart Use of Distributed Systems and Localization and Attack from UAVs
 - (d) Multi-Torpedo Salvo Defense
6. Time Critical Strike
 - (a) Aircraft Integrated Self-Protection Suites
 - (b) Persistent High Speed Strike Weapon to Engage Time Critical Targets
 - (c) Detect and Engage Moving Targets
 - (d) Discriminate and Provide Terminal Guidance for Weapons Targeted at
 - (e) Moving Targets
7. Missile Defense
 - (a) Advanced Electronic Sensor Systems
 - (b) Long Range RF Detection, Tracking, Deception and Jamming

- (c) Sea Based Missile Defense of Ships and Littoral Installations
- 8. Fleet/Force Protection
 - (a) Intent Determination – EO/IR Enhancements, Proof-Of-Concept,
 - (b) Non-Lethal Approach
 - (c) Full Spectrum Defense vs. Asymmetric Threats
 - (d) Small Boat Detection With Proof Of Concept Non-Lethal Approach
- 9. Littoral Combat Power Projection
 - (a) Advanced Naval Fires Technology
- 10. Advanced Capabilities Electric Systems
 - (a) Battlefield Power
 - (b) Pulsed Power
 - (c) Quiet Drives and Ship Fuel Cell Systems

TABLE A-2. POM-06 PRIORITIZED GAPS AND ENABLING CAPABILITIES

USMC & N3-N5 Gap 1: Urban Counter-Terrorism (new)
Urban/Asymmetric Ops EC-1: Improvised Explosive Devices Spiral 1
Urban/Asymmetric Ops EC-2: Hostile Fire Detection and Response Spiral 1
Urban/Asymmetric Ops EC-3: Hostile Fire Detection and Response Spiral 2
Urban/Asymmetric Ops EC-4: Position-Location-Information
Urban/Asymmetric Ops EC-5: Fortified Position Security
Urban/Asymmetric Ops EC-6: Defense of Harbor and Near-Shore Naval Infrastructure Against Asymmetric Threats.
Urban/Asymmetric Ops EC-7: Improvised Explosive Devices Spiral 2
Urban/Asymmetric Ops EC-8: Hostile Fire Detection and Response Spiral 3
Urban/Asymmetric Ops EC-9: Transparent Urban Structures
Urban/Asymmetric Ops EC-10: Modular Scalable Weapon
OMCM Gap 1: Capacity to Clear Large Areas of Mines w/o Cued ISR
OMCM EC-1A: MCM Capacity Spiral 1
OMCM EC-1B: MCM Capacity Spiral 2
OMCM EC-1C: MCM Capacity Spiral 3
KSA Gap 1: Joint Combat ID
KSA EC-1A Improved Cooperating/Non-Cooperating Target Situational Awareness
KSA EC-1B Real-Time Long Range Air Defense Combat ID in Support of Early Engagements
KSA EC-1C Combat ID information Management of Coordinated Electronic Surveillance
KSA EC-1D Data Fusion for Combat ID to Reveal Contact Intent
KSA EC-1E COCOM to Marine Combat ID.
EXLOG Gap 1: Strategic Mobility to Move Forces Rapidly to the Sea Base
EXLOG EC-1A Sea Base Integrated Operations
EXLOG EC-1B Sea Base Mobility and Interfaces
EXLOG EC-1C Sea base Interface Connectors for Persistence
KSA Gap 7: Persistent ISRT for Accurate Target Discrimination & Location
KSA EC-7A Enhance Warfighter Use of ISR
KSA EC-7B Multi-Source ISR to the Warfighter
KSA EC-7C Dynamic Target Engagement & Enhanced Sensor Capabilities
KSA EC-7D Automated Control of Large Sensor Networks
KSA EC-7E Advanced Sensors
KSA EC-7F Unmanned Combat Air Vehicle

KSA EC-7G Marine and UxV Tactical ISR
KSA EC-7H Data Fusion to Identify Adversary Intent
LASW Gap 1: Rapid Sub Cueing, Detection & Localization in Shallow & Deep Water
LASW EC-1A Surveillance, Search, and Localization Sensor System Performance and HWT improvements
LASW EC-1B Rapid, Covert Surveillance System Deployment and LWT Improvement
LASW EC-1C Cross Field Processing and Smart Use of Distributed Systems and Localization and Attack from UAVs
TCS Gap 2: Survivability of Aircraft Operating at Low Altitude
TCS EC-2A: Aircraft Integrated Self-Protection Suites
TCS EC-2B: Aircraft Protection Suite Modernization
MD Gap 1: Sea Based Missile Defense of Ships & Littoral Installations
MD EC-1A Advanced Electronic Sensor Systems for Missile Defense
MD EC-1B Long Range RF Detection and Tracking
MD EC-1C Long Range RF Deception and Jamming
MD EC-1D Over-the-Horizon Missile Defense
MD EC-1E Sea Based Missile Defense of Ships and Littoral Installations
KSA Gap 2: Optimal Mix of Naval Sensors To Complement Joint & National Capabilities to Meet Naval Mission Requirements
KSA EC-2A: Optimal Mix of Large Manned/Unmanned Sensor Networks
KSA Gap 3: Computer Network Defense & Information Assurance
KSA EC-3A Secure Collaboration
KSA EC-3B Trusted Processing
TCS Gap 3: Persistent High Speed Strike Weapon to Engage Time Critical Targets
TCS EC-3A: Persistent High Speed Strike Weapon to Engage Time Critical Targets
TCS Gap 4: Weapons with Standoff & Fire-and-Forget Capability against Moving Targets
TCS EC-4A: Detect and Engage Moving Targets
TCS EC-4B: Discriminate and Provide Terminal Guidance for Weapons Targeted at Moving Targets
LASW Gap 2: Platform Defense against Undersea Threats, Including Ship Self-Defense against Multi-salvo Torpedo Attacks
LASW EC-2A: Two-Torpedo Salvo Defense
LASW EC-2B: Four-Torpedo Salvo Defense
KSA Gap 4: Ubiquitous, Secure Communications & Network Infrastructure
KSA EC-4A Joint Maritime Communications & Networking
KSA EC-4B Advanced Communications for FORCEnet
KSA EC-4C GIG-Compliant Networking
KSA EC-4D GIG Dynamic Tactical Networking
EXLOG Gap 2: Sea Based Sustainment CONOPS & Capacity for Persistent Combat Operations
EXLOG EC-2A: Sea Based Collaborative Command and Control
EXLOG EC-2B Sea Based Collaborative Planning
OMCM Gap 2: Destruction of Mines in Areas through which Marine Corps & Joint Forces must Maneuver from Deep Water to SZ & BZ
OMCM EC-2A: MCM for Maneuver Spiral 1
OMCM EC-2B: MCM for Maneuver Spiral 2
OMCM EC-2C: MCM for Maneuver Spiral 3
KSA Gap 5: Link Management & Architecture
KSA EC-5A Link Management & Architecture
KSA Gap 6: Common & Persistent Maritime Picture on/below Surface
KSA EC-6A GIG-ES UDOP & Decision Making
KSA EC-6B Next-Generation Command, Control & Decision Support Services
KSA EC-6C Trusted Combat C2 Capabilities

FFP Gap 2: Adequate Detection & Engagement of Terrorist & SOF Threats to Ships Inport & Transitioning
FFP EC-2A: Intent Determination – EO/IR enhancements, proof-of-concept for non-lethal approach
FFP EC-2B: Full spectrum defense vs. asymmetric threats
LCPP Gap 2: Naval Fires to Support Speed/Depth of Marine Corps and Joint Maneuver
LCPP EC-2A: Advanced Naval Fires Technology Spiral 1
LCPP EC-2B: Advanced Naval Fires Technology Spiral 2
FFP Gap 3: Counter Small Boats
FFP EC-3A: Small Boat detection w proof of concept non-lethal approach
FFP EC-3B: Long range detection and precision engagement vs. coordinated small boats
TOC Gap 1: Turbine Engine
TOC EC-1A Turbine Engine: Reduce cost of Operations 1
TOC EC-1B Turbine Engine: Reduce cost of Operations 2
TOC Gap 2: Reduced Support Costs
TOC EC-2A Reduce support costs 1
TOC EC-2B Reduce support costs 2
ACES Gap 1: Advanced Pulsed Power
ACES EC-1A: Quiet Drives and Ship Fuel Cell Systems
ACES EC-1B: Pulsed Power
ACES EC-1C: Power Distribution and Control
ACES Gap 2: Battlefield Power
ACES EC-2A: Battlefield Power

TABLE A-3. EXAMPLE CALCULATIONS

Parameters	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6
Ng	100	100	75	100	75	100
Na	2	2	2	2	2	2
Np/a	3	3	3	3	3	4
Nproj	600	600	450	600	450	800
Ns	2	2	2	2	2	2
Ne	2	3	2	2	3	2
Ns&t	2400	3000	1800	2400	2250	3200
Pover	0.1	0.1	0.1	0.1	0.1	0.05
n	1	1	1	1	1	1
WY	150,000	150000	150000	150000	150000	150,000
P%infra	0.1	0.1	0.1	0.1	0.1	0.1
Cpeople	\$711,630,000	\$810,630,000	\$612,630,000	\$756,720,000	\$731,970,000	\$909,810,000
Cinfra	\$71,163,000	\$81,063,000	\$61,263,000	\$75,672,000	\$73,197,000	\$90,981,000
Ctotal	\$782,793,000	\$891,693,000	\$673,893,000	\$832,392,000	\$805,167,000	\$1,000,791,000
Nwh	167	167	167	167	167	167
Navgwhp	60	60	60	60	60	60
Pps&t	0.3	0.3	0.3	0.3	0.3	0.3
Poverlap	0.3	0.3	0.3	0.2	0.2	0.1
Nwhp	2104	2104	2104	2405	2405	2705
Npeople	2640	3300	1980	2640	2475	3360
*percentage	1.45%	1.81%	1.09%	1.45%	1.36%	1.85%
Ntotal	4744	5404	4084	5045	4880	6065
*percentage	2.61%	2.97%	2.25%	2.77%	2.68%	3.33%

*Percentages are of the FY 03 Navy civilian workforce of 181,902

Figure A-3 lists the parameters that we need to know.

Ng = Number of Naval Capability Gaps
 Na = Number of approaches per Gap
 Np/a = Number of projects per approach
Nproj = Number of annual projects
 Ns = number of scientists per project
 Ne = Number of engineers per project
Ns&t = S&E staffing level for Ng Gaps
 Pover = fractional overhead
Npeople = adjusted number of people supporting Ng Gaps
 n = personnel cost multiple, ≥ 1
 WY = consolidated work year rate
Cpeople = total people cost
Cinfra = annual infrastructure cost
Ctotal = total annual cost – infrastructure plus people
 Nwh = number of Warrant Holders
 Pps&t = fraction of the pyramid people S&T trained
 Navghwp = average number of people in a technical pyramid
 Poverlap = fractional overlap between pyramids and Gaps
Nwhp = number of Warrant Holders support people
Ntotal = total S&T workforce people

FIGURE A-3. PARAMETERS NEEDED

Figure 14 correlates to Figure A-3.

A.12 CONCLUSION

This algorithm (i.e., Equations A-9, A-20, and A-21) represents an approach to answering the questions **“How much Navy S&T do we need?”** **If not “zero,” then how much is enough?**

Defining the problem, we want to solve approaches the first part; that is, what does the navy need that S&T can facilitate or enable? We have chosen the Capability Gaps as the answer to this question because they are widely accepted. Then the problem is preparing a proposal, so to speak, for accomplishing that work, i.e., determine the staffing needed for the many projects focused on the Capability Gaps. The process is then to set the parameters and compute the answer. The issue is to reach agreement on the parameters.

Given that the right people can agree to a set of parameter values, the next question, finding the minimum workforce necessary, is not so easily accomplished. The 1998 DSB Task

Force presented an approach to this minimization problem by hypothesizing a capability function and to compute the workforce. Then you simply differentiate the workforce ---or something like this. However, they concluded that the capability function could not be determined at that time.

Our approach, while also struggling with some lack of clarity in setting parameters, at least allows us to discuss the variables and look at sensitivities.

In the end, we do know something about the answer – what we do today, what others have felt was appropriate, and what our collective experience tells us.

So, when our leaders ask, **How much S&T do I need?**, we can respond with a set of options spanning various sets of desired capabilities.

Table A-4 shows a 9-year span of funding versus output.

TABLE A-4. OUTPUT VERSUS FUNDING

Output	1993	1994	1995	1996	1997	1998	1999	2000	2001
# "Transitions"	No Data	38	35	41	33	38	44	49	50
# Projects (~#PIs, not FTEs)	181	197	218	214	206	192	183	195	198
Published Papers	393	270	259	225	250	261	270	202	203
Submitted Papers	110	90	82	74	59	17	19	54	109
Books/Chapters	52	7	20	19	6	8	13	16	8
Patents/Patent Applications	79	67	69	72	93	98	99	105	94
Government Reports	76	62	68	56	38	27	20	8	19
Dissertations	37	10	13	5	3	1	6	5	3
Presentations	417	259	369	248	248	234	234	229	220
Awards/Honors	79	52	68	39	41	39	48	19	14
Funding (M)	\$15.4	\$16.8	\$17.0	\$15.0	\$13.7	\$13.1	\$13.0	\$14.2	\$14.4

APPENDIX B

**PRESENTATION: SCIENCE AND TECHNOLOGY METRICS
AND OTHER THORNY ISSUES**

APPENDIX B

**PRESENTATION: SCIENCE AND TECHNOLOGY METRICS
AND OTHER THORNY ISSUES**

The slides that follow comprise the presentation given to Captain Joseph McGettigan on 12 April 2005. As shown, it has the authors' raw notes and asides on individual slides that provide insights into the thoughts that went into creating presentation. The numbering of these slides is formatted to match the numbering scheme of this appendix.

In addition, the Note Pages, where applicable, are included after the slide to which they are relevant.



DRAFT

Science and Technology at Navy Labs

Metrics...and other thorny issues.

12 April 2005

8th try



Prevailing Impressions & Attitudes

- We'll never get anything out of S&T.
- S&T is a sandbox operated for the benefit of the scientists.
- Level-of-effort programs are inefficient, stagnant, and non-productive.
- Industry will invent and develop everything we need.
- During a war S&T can be given a lower priority and placed on the back burner.
- "The DOD labs, created for the purpose of technology transition, are widely judged to be incapable."



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- **"The DOD labs, created for the purpose of technology transition, are widely judged to be incapable."**

28 January 2005

While the title of this presentation addresses Metrics of S&T first, we want to begin with one of the Thorny Issues, that is , a set of prevailing impressions and attitudes about Navy laboratories that seems to keep coming up around the Navy, the DOD, and even the government in general. This list captures some of the key (mis)impressions that we will attempt to counter throughout this material.



One more

"The DoD should be more ruthless about cutting defense labs. There is little these labs offer that the private sector can't match. While some capabilities are unique to the [DoD], these are far fewer than their proponents will admit, and many hark back to technologies that have long since been bypassed in the private sector...the need for a large defense laboratory structure is simply indefensible..." Source: Dov Zakheim, CEO, SPC International, 17 Jun 97 HASC testimony.

We could find no evidence to support these claims



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We could find no evidence to support these claims

28 January 2005

And a final unsubstantiated statement in a public forum.



Assertions – what *we* believe

1. In-House S&T has great value to the Naval Enterprise.
2. The level of S&T required to support the Navy is independent of the number of ships or sailors. Rather it depends only on what technologies are deployed and what might be needed in the future.
3. It is clear that the Navy wants the benefits of new S&T. (...at a “reasonable” cost)
4. Low hanging S&T “fruit” is a myth.
5. The loss of institutional technical competence leads to failure.
6. S&T projects never go according to plan.

The validity of these “beliefs” will be examined and supported in this presentation.



The Process

This study began as a study of S&T Metrics in response to questions from NAVSEA: What is the Return-on-S&T Investment? And How much S&T is Needed?

The difficulty of these questions, and the long discussions that followed led to new directions.

Members of the Dahlgren Division *Science and Technology Council* participated in the discussions, July 2004 to March 2005.

Our conclusions which follow reflect the scope of issues covered in this effort.



Our Conclusions – S&T Metrics

- Metrics can supply evidence that the basic S&T assertions in this brief are relevant.
- S&T metrics can be defined and collected in response to specific questions, but you tend to get what you choose to measure.
- The immediate ROI for Navy S&T is its contribution to the quality and development of “our people, (*who*) will determine our future success”* ...or failure.
- Transitions and speed-of-transition are not significant measures of S&T performance. They may be better measures of how well the entire RDT&E acquisition process is working.
- A better measure of S&T is how well is Navy S&T addressing current and future Navy needs, and how prepared is the workforce to address those needs.
- The size of the Navy S&T budget and in-house workforce should be determined by what you want it to do, I.e. what Navy capabilities need to be enabled.



Gems

- *“Peer Review is the Sacred Cow of S&T Metrics.”*
- *“S&T outcomes are imagined and brought to reality by scientists, engineers and technologists. Yet these outcomes are applied, misapplied, and used/abused by leaders or managers in government and industry, who do not adequately understand them, their potential, and their power.”*
- *“Be careful what you measure. What you measure is what you will get.”*
- *“Technical competence requires technical tasking.”*

There are volumes of material on this subject. We have examined over 100 books, papers and briefs. Here are a few we have found useful:

- B-13



Study Outline

- I. Return on S&T Investment**
- II. Technology Transitions**
- III. Assertions.** These are what we believe, and attempt to demonstrate with argument, historical examples and data.
- IV. S&T Metrics: Should be collected in response to specific questions from “evaluators”.** Several questions are proposed that might be of interest at all levels of management.
- V. Potential metrics** Metric Data collection is not a trivial enterprise.
- VI. Conclusions**
- Appendix A: How much is enough?** (Appropriate size of the S&T Workforce)
- Appendix B:** Metrics for our Value statements.
- Appendix C:** Historical Examples of Dahlgren products of S&T that have transitioned.
- Appendix D:** Examples of disruption in the scientific workforce leading to failure.



I. Return on S&T Investment

The ultimate return on S&T investment might be captured in this observation, referring to the end of the cold war:

“In a way our science and technology capability has acted as an additional form of deterrence against our adversaries.” *

“The ability to learn faster than your competitors may be your only sustainable competitive advantage. **

**“Making predictions is tough – particularly about the future.”
Niels Bohr.**



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Niels Bohr.**

28 January 2005

- * “Transforming Defense Basic Research Strategy”, Augustus W. Fountain, III, from *Parameters*, Winter 2004-05, Vol. XXXIV, no 4. pages 40 to 54. *Parameters* is the US Army War College Quarterly.
- ** Defense S&E Workforce Transformation: The Way Ahead. Statement by Arie de Geus, Royal Dutch Shell, Former Strategic Planner.



I. RETURN ON S&T INVESTMENT

We have identified three areas-overlapping and interconnected –where the expenditure of Navy funds and the use of Navy in-house personnel produce a “Return to the Navy” for the dollar or people investment in S&T.

A. New Technologies that can transition to new Navy capabilities.

- ***Fill capability gaps.***
- ***Solve specific technical problems.***
- ***Create entirely new capabilities.***

B. “Risk” Reduction throughout the acquisition process.

- ***Decrease the risk of technological surprise.***
- ***Decrease the risk of acquiring expensive, unreliable, maintenance intensive systems.***
- ***Decrease the risk of delaying program execution due to immature technologies.***
- ***Decrease the risk of failing to recognize future threats or needed capabilities.***
- ***Decrease development risk by facilitating the transition of appropriate technologies (people “transition” to acquisition as well as technologies)***

C. Contributions to ensuring a prepared and experienced technical workforce, supporting in-house technical authority, and maintaining a continuity of core competencies.

The following viewgraph is a attempt to capture “Navy ROI for S&T” in a single chart.

I. RETURN ON NAVY IN-HOUSE SCIENCE AND TECHNOLOGY INVESTMENTS

<p>Return to the Navy:</p> <p>A S&T workforce that is prepared and equipped to effectively meet mission technical needs; Contribute to the total acquisition process through decreasing the risk of failure in meeting Navy Technical Capability needs in both the near and far term. Avoid technological surprise. Provide continuity of technical capability in core technical areas.</p> <p>Requires:</p> <ul style="list-style-type: none"> Wide Spectrum of Talent Deep Experience Base Deep Knowledge Base (Core Capabilities) A Few Visionaries <p>Examples:</p> <ul style="list-style-type: none"> Quick Reaction Technical Response <ul style="list-style-type: none"> —Viet Nam, Desert Storm, Iraqi Freedom Multi-Decade Program Support <ul style="list-style-type: none"> — FBM, Aegis, Tomahawk, STD Missile, CIWS, Gun Systems, System Safety, HERO, EMI/EMC, Chem./Bio Defense <p>Metrics/Indicators:</p> <ul style="list-style-type: none"> Health of technical base Cost of risk reduction/cost of consequence Customer Assessments NFFTL, D&I, FNC, INP program support Technical Pyramid support 	<p>Return to the Navy:</p> <p>Successful transition of externally developed technologies into operational use by USN/USMC. Improved future operational costs and performance. Decreased risk of acquiring expensive, unreliable, maintenance-intensive systems.</p> <p>Requires:</p> <p>The technical competence to interact with industry, universities, other government agencies, other services, foreign government agencies and institutions; and to apply the knowledge to USN/USMC systems and problems.</p> <p>Examples:</p> <ul style="list-style-type: none"> NSWC Missile launcher collaboration with Lockheed Martin, General Dynamics Army and DARPA Net Fires for LCS ESSM, Penguin, and NULKA international programs <p>Metrics/ Indicators:</p> <ul style="list-style-type: none"> Cost Avoided, Lives Saved Enhanced health/safety Improved System Capability New Capabilities Enabled 	<p>Return to the Navy:</p> <p>Technology developed, prototyped, and transitioned to fielded capabilities. Decreased risk of delaying program execution due to immature technologies.</p> <p>Requires:</p> <ul style="list-style-type: none"> Engaged workforce that can identify needs and potential technical solutions. Technical capacity to contribute to the development of solutions. Strong connections to PM/PEO organizations that will develop, acquire, and support the solutions. Strong connection to operational units that will use the solutions. <p>Examples:</p> <ul style="list-style-type: none"> EO tracking for Phalanx CIWS Onboard Mission Planning for Tomahawk EMI filter for Zuni and 2.75 rockets Warheads for Std. Missile and Phoenix SAL guidance for projectiles and bombs AN/KAS-1 Chemical Cloud Detector <p>Metrics/ Indicators:</p> <ul style="list-style-type: none"> System Improvements (MTBF, MTTR) Past Transitions Reduced Manning Current S&T Coverage of Gaps
---	--	---

In-House S&T Enables Responding to Problems and Filling Capability Gaps



I. Return on investment = Results

Four very recent examples of ROI

- Three *already used* in the War against Terrorism:
 - *Advanced Conventional Munitions* (synthetic organic chemistry, rheology)
 - *Advanced Chemical and Biological Sensors* (surface chemistry, polymer chemistry, surface acoustic wave science, molecular biology, immunology)
 - *Advanced Explosives Detection* (nuclear quadrupole resonance)
- One that soon may be:
 - *Real-Time Detection of Hidden Pathogens* (RF science, signal processing)

Caution: To show examples trivializes the results of S&T investment. It is too tempting to equate a few bullets with the \$2B annual investment.



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28 January 2005

Liszka 2002



I. Return on Investment

History of Military Critical Technology Developments

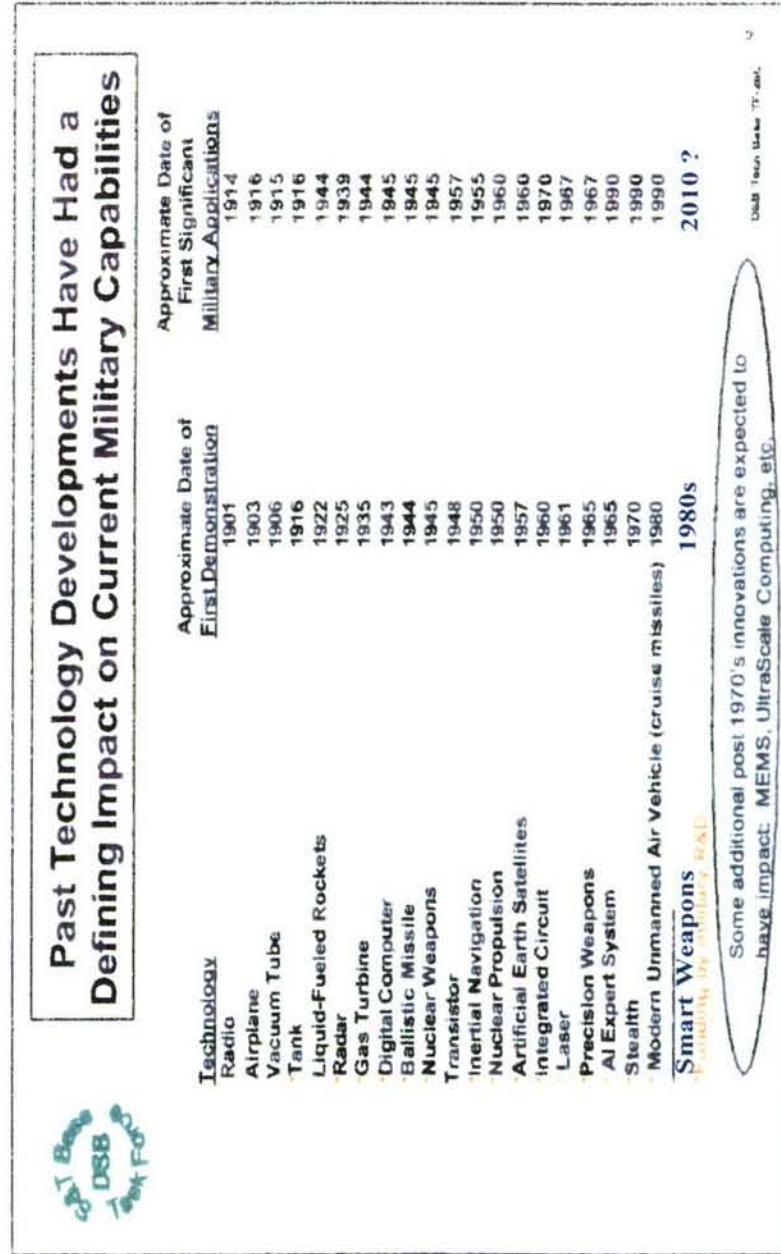


Fig. 1 History of Military Critical Technology Developments



I. Return on Investment

History of Military Critical Technology Developments

Past Technology Developments Have Had a Defining Impact on Current Military Capabilities

Technology	Approximate Date of First Demonstration	Approximate Date of First Significant Military Applications
Radio	1901	1914
Airplane	1903	1916
Vacuum Tube	1906	1915
Tank	1916	1916
Liquid-Fueled Rockets	1922	1944
Radar	1925	1939
Gas Turbine	1935	1944
Digital Computer	1943	1945
Ballistic Missile	1944	1945
Nuclear Weapons	1945	1945
Transistor	1948	1957
Inertial Navigation	1950	1955
Nuclear Propulsion	1950	1960
Artificial Earth Satellites	1957	1960
Integrated Circuit	1960	1970
Laser	1961	1967
Precision Weapons	1965	1967
AI Expert System	1965	1990
Stealth	1970	1990
Modern Unmanned Air Vehicle (cruise missiles)	1980	1990
Smart Weapons <small>(Pending by Military R&D)</small>	1980s	2010 ?

Some additional post 1970's innovations are expected to have impact: MEMS, UltraScale Computing, etc.

DSB Tech Brief 11-2002 V

28 January 2005

Fig. 1 - History of Military Critical Technology Developments

Defense Science Board
Comments
on Smart Weapons
DUSD(S&T) Smart Weapons
Workshop
4 December 2002

Arthur P. McGregor
Associate Director for Conventional
Weapons
Office of the Deputy Under Secretary of Defense
(Science & Technology)
703-588-7406



I. Return on S&T Investment - cont

“Dollars returned for dollars invested”, as industry would want to answer the question, is perhaps impossible to compute for a Navy R&D Laboratory for several reasons:

- a. We do not sell our products
- b. Long delays between when S&T shows feasibility and when a technology is actually used to enable an operational fleet capability.
- c. Lab responsibility is to enable the warfighter and solve unanticipated problems – quickly.
- d. The “dollars” returned are to the Big Navy, not the Lab. And might be in dollars NOT spent rather than increased revenue.

Rather, return on S&T Investment is the inherent capability of the S&T trained workforce to respond when needed, to recognize needs years in advance of fleet perception of the need, anticipate threats, and generally be the font of continuous knowledge about current and future Navy systems.

A competent workforce is the Near-Term Navy ROI for S&T.



I. Return on S&T Investment

From: DARPA Strategic Plan, “Bridging the Gap”, Feb 2005

“As military historians note, None of the most important weapons transforming warfare in the 20th century – the airplane, tank, radar, jet engine, helicopter, electronic computer, not even the atomic bomb – owed its initial development to a doctrinal requirement or request of the military.” *None* of them. And to this list, DARPA would add unmanned systems, stealth, global positioning system (GPS) and Internet technologies.”

John Chambers, ed., *The Oxford Companion to American Military History* (New York: Oxford University Press, 1999) p. 791.

If they don’t know what to ask for then someone has to tell them what they need. This is ROI.



I. Return on S&T Investment

TRANSFORMATION'S TRAJECTORY

Art Cebrowski, former director,

Office of Force Transformation

3 March 2005

“R&D is really quite nuanced. There is a texture to it. How much money are you going to allocate to reinforce decisions already made in the past? For example, if you decide you are going to do a Joint Strike Fighter and it develops a problem in development you may have to put some significant money against it. This is money that has to come from somewhere else in the R&D accounts. Perhaps by cutting money earmarked for university research? Possibly by reducing funding for defense labs. More importantly, however, what is being shortchanged is the process of discovery and invention. As the department moves into a period of uncertainty, discovery and invention are increasingly important.”

“The department must look at the economics of R&D from a strategic point of view. The great power of America is really our human capital—our brainpower. Historically, when money is moved into certain research areas, there is a mirror image movement in the percentage of PHD candidates in those areas of emphasis. It is an indication of the strategic power of R&D. But, if the department is spending a disproportionate share of precious R&D by shoring up decisions previously made, we are losing some of that strategic power. In times of uncertainty, especially, this is what is going to ultimately give us the breadth of development to make decisions on relatively short timelines.”



I. Return on S&T Investment - cont

The Importance of S&T to Technical Workforce Quality

1. S&T projects provide a critical training experience for the future technical workforce.
2. The availability of “hands-on” S&T projects provides a critical “attractor” for recruiting the right new talent that is needed to maintain the technical workforce in the long term.
3. S&T experience is highly correlated (we believe) with the probability that an individual is/will become a senior technical manager or leader.
4. The three assertions above for S&T can also be made for hands-on T&E.
5. Analogous or parallel assertions can be made for other professions – e.g. Medical Doctors, and Military professionals.



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Feb 16, 2005

Subj: Research and Engineering Goals

“These goals apply to all DoD components conducting R&E.”

“There are several Enabling Technology Goals that may not lead directly to systems, but are vital for enhancement of military capability. The DoD should increase emphasis to advance capabilities in the following enabling technology areas:

1. Nanotechnology
2. Biotechnology
3. Unmanned and autonomous systems
4. Quantum Communications/computing technology
5. Networked systems
6. Advanced materials
7. Intellectual capital(workforce)
8. DoD R&E infrastructure
9. Modeling, simulation, computation, and software for complex systems.”



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28 January 2005

We include this chart to show that this idea that S&T is a significant contributor to workforce development is not revolutionary. Mr. Ron Sega issued these goals to the DoD and included #7, "Intellectual Capital (workforce)" as an enabling technology.



I. ROI Summary

It is widely accepted that ROI, and metrics in general, are difficult to define for S&T.

Many Military capabilities can be linked directly to S&T discoveries.

Many kinds of Risk are reduced, including the risk of technological surprise.

A competent workforce is the Near-Term Navy ROI for S&T.

No Investments – No Starships !

Appendix C contains some examples of Dahlgren's S&T products.



II. S&T Transitions

A Requirement is a “PULL” Action

- S&T Provides the shopping list
- Acquisition provides the money for development

S&T has no control over this kind of money.

Therefore S&T cannot control transitions.

- ACTDs work because the Services commit the money.
- FNCs do not work well because there is no actual Navy commitment of acquisition money.



II. Transitions - The Problem

- The Navy S&T program performs research and identifies , develops and demonstrates technologies. In addition, it significantly enables the recruiting, training, and retention of a quality technical workforce.
- True S&T, by its nature, does not have a “guaranteed” output or result, and does not deliver on predetermined deadlines.
- “Failure to transition” is often NOT due to poor S&T or irrelevant S&T.
- Numerous ONR, ASN and OSD leaders and programs have recognized this situation and have attempted to institute solutions.
 - ONR/OP91: ATDs, FNCs, TechSolutions
 - ASN: CTTO*, Rapid Technology Transition (RTT) program
 - OSD: ACTDs, Tech Transition Initiatives, Quick Reaction Fund...
- A specific example from a recent OUSD(AS&C) brief follows:



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- True S&T, by its nature, does not have a “guaranteed” output or result, and does not deliver on predetermined deadlines.
- “Failure to transition” is often NOT due to poor S&T or irrelevant S&T.
- Numerous ONR, ASN and OSD leaders and programs have recognized this situation and have attempted to institute solutions.
 - ONR/OP91: ATDs, FNCs, TechSolutions
 - ASN: CTTO*, Rapid Technology Transition (RTT) program
 - OSD: ACTDs, Tech Transition Initiatives, Quick Reaction Fund...
- A specific example from a recent OUSD(AS&C) brief follows:

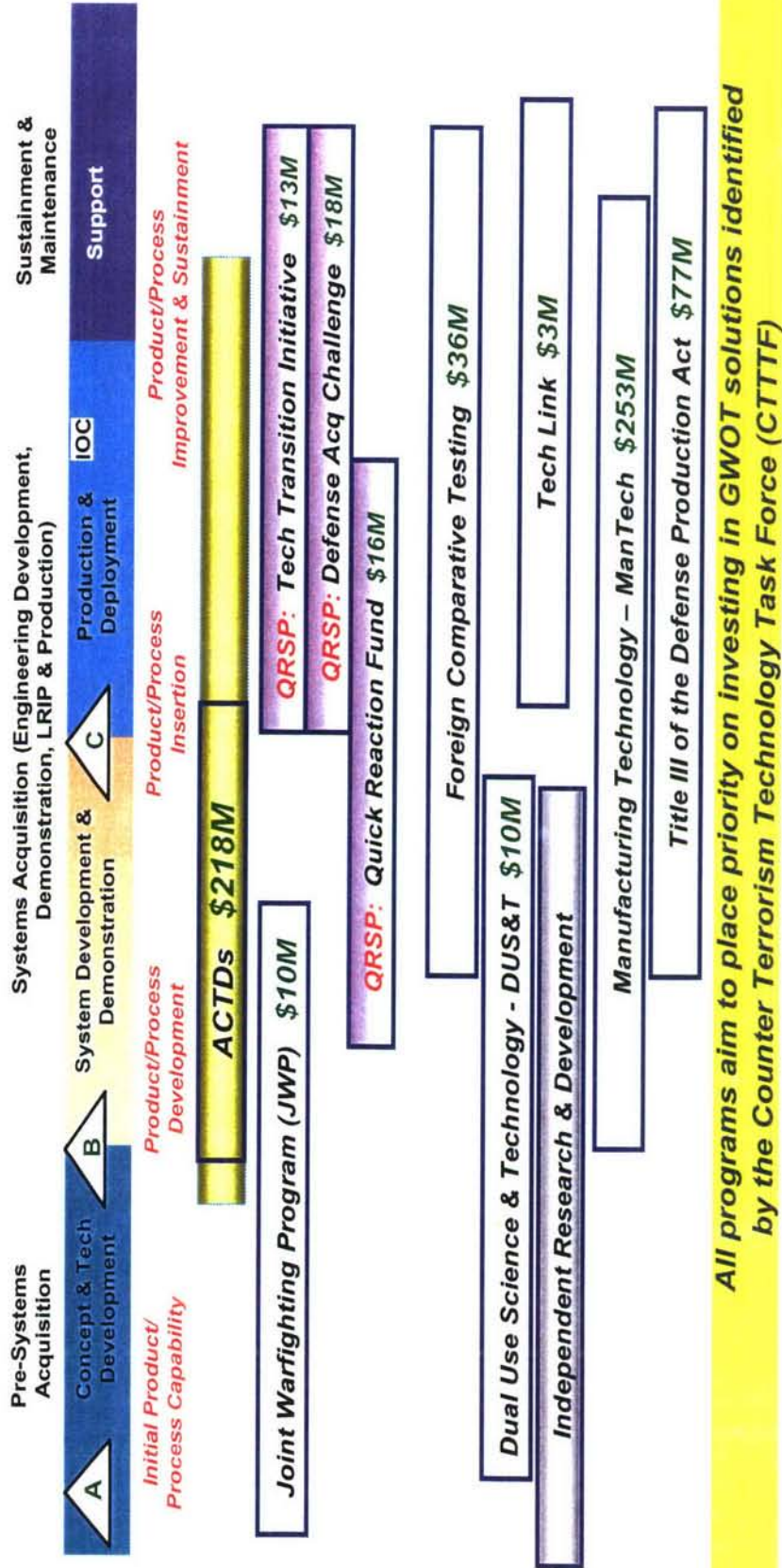
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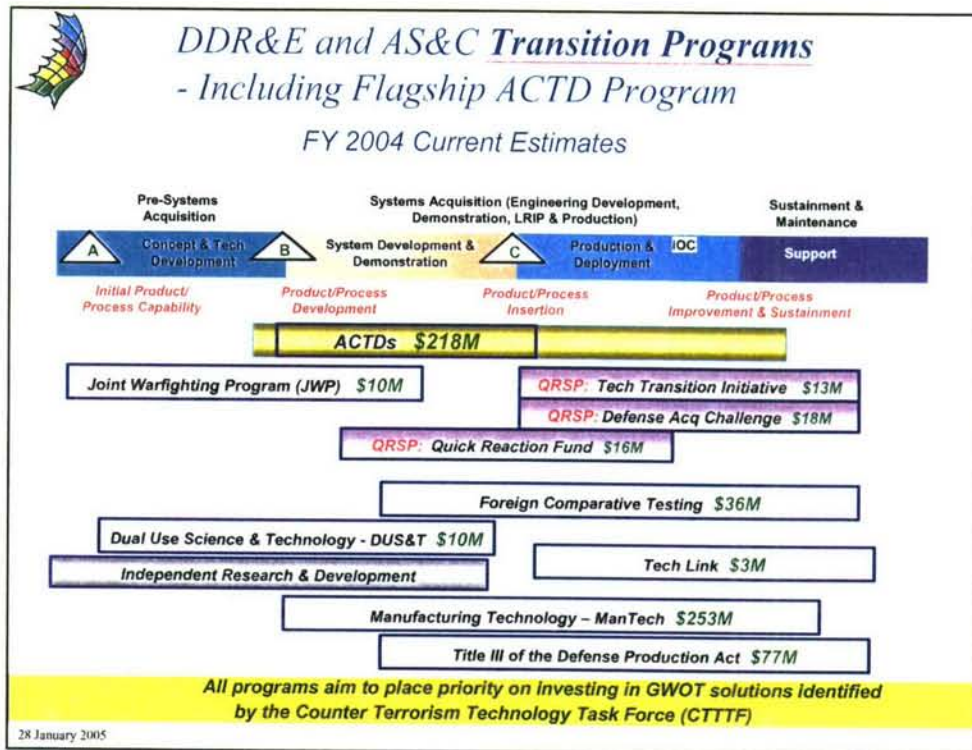
* CTTO: Chief Technology Transition Officer



DDR&E and AS&C Transition Programs - Including Flagship ACTD Program

FY 2004 Current Estimates





- Advanced Concept Technology Demonstration-“What’s New with ACTDs?”
Ms. Sue Payton, Deputy Under Secretary of Defense, Advanced Systems & Concepts
PACOM Conference Brief – 10 March 2004
- “Tool Box” of Transition Tools available.
- The graphic represent FY-04 and FY-05 Defense Wide RDT&E funding. These resources leverage Defense Agency and Military Service programs, helping provide a much quicker transition to the warfighter.
- The MANTECH, Dual Use, and IR&D lines are funded through Service Program Elements.
- **Note for AS&C:** FY-04 is the “Current Estimate.” (adjusted for Congressional Rescissions, SBIR Taxes, withholds etc...) The FY-05 number is the President’s Budget Submission . These are the \$\$ numbers the Hill is looking at

• ADM Giambastiani (USN) (JFCOM CDR) comments:
JFCOM has been empowered with 'Technology Authority' which gives them the financial Laboratories.
This is the authority to issue CRADAs. There is no money associated with this authority.
JFCOM plans to be the 'Voice of Research and Technology' to be associated with the Office of Research and Technology. **Richards.**

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II. Transitions – Some Reasons for Failure

- Technology development effort failed to reach a successful outcome.
- Technology development product was no longer needed or wanted when it was ready.
- Technology product was still needed, but other issues had higher priority.
- Technology effort was focused on the “wrong” issue from inception. (Predictions of future needs are never completely accurate.)
- When the technology product was ready, funding was not available for further development and transition.
- Technology product was too expensive or too complex.
- Competing technologies or solutions prevailed. (e.g. VHS vs BETA)

Transitions happen when there is a strong requirement “pull” and an appropriate technology already exists.



II. Transitions

Should be specifically managed, Perhaps as part of Budget Activity 4, or a special Program Manager.

RDT&E Categories - The names changed in 2003.

BUDGET ACTIVITY 1, BASIC RESEARCH.

Basic research is defined as systematic study directed toward greater knowledge or understanding of the fundamental aspects of phenomena and of observable facts without specific applications towards processes or products in mind.

BUDGET ACTIVITY 2, APPLIED RESEARCH.

Applied research is defined as systematic study to gain knowledge or understanding necessary to determine the means by which a recognized and specific national security requirement may be met.

BUDGET ACTIVITY 3, ADVANCED TECHNOLOGY DEVELOPMENT.

Includes development of subsystems and components and efforts to integrate them into system prototypes for field experiments and/or tests in a simulated environment

BUDGET ACTIVITY 4, ADVANCED COMPONENT DEVELOPMENT AND PROTOTYPES, and Transitions *TRANSITION MIGHT BE ADDED HERE*

Includes all efforts necessary to evaluate integrated technologies, representative modes or prototype systems in a high-fidelity and realistic operating environment.

BUDGET ACTIVITY 5, SYSTEM DEVELOPMENT AND DEMONSTRATION.

Includes those projects that have passed Milestone B approval and are conducting engineering and manufacturing development tasks aimed at meeting validated requirements prior to full-rate production.

BUDGET ACTIVITY 6, RDT&E MANAGEMENT SUPPORT.

Includes research, development, test and evaluation efforts directed toward sustainment and/or modernization of installations or operations required for general research, development, test and evaluation.

BUDGET ACTIVITY 7, OPERATIONAL SYSTEM DEVELOPMENT.

Includes those development efforts to upgrade systems that have been fielded or have received approval for full rate production and anticipate production funding in the current budget or subsequent fiscal year. Program elements in this budget activity are coded using the Major Force Program of the fielded system in the first two positions (e.g. 01 indicates a strategic system).



II. Transitions

Necessity: Mother of Development

Microsoft's Advanced Technology Center (ATC), opened in November 2003, takes up half of one floor of a six-floor office building in the Haidian district of northwest Beijing—the same edifice occupied by Microsoft Research Asia, one of six research labs worldwide that Microsoft operates. **Enhancing the transfer of technology** between the 170-strong research facility and product development groups at Microsoft's headquarters in Redmond, WA, is the whole reason the center exists, and the close proximity to the lab makes handoffs easier.

Zhang, who worked on technology transfer at Hewlett-Packard Labs before being recruited as a charter researcher at the Beijing lab, says the issues spurring the ATC's creation are common to all research and development-driven organizations. After researchers hand off an invention or a new piece of code to product developers, a lot of refinement and testing is needed to get it ready for commercial release, and the product developers aren't always able to do it. They often have their hands full with more pressing jobs—say, upgrading conventional features or improving security. And even a great invention might arrive at the wrong point in the product development cycle, where it's difficult to fit into the next release. "Which means that for the product group to form a team and take that risk [of developing the invention] may be too big a risk and too big a distraction," says Zhang. "Microsoft: Getting from R to D"



II. Transitions- Summary

- ONR, ASN, and OSD recognize that bridging the “Valley of Death” between S&T and Acquisition requires programs and people dedicated to enabling Technology Transition.
 - S&T Metrics – Quality and Relevance
 - Acquisition Metrics: Budget, Schedule, and Performance
 - Transition Program Metrics: Successful Technology Transitions
- Transitions and speed-of-transition are not significant measures of S&T performance. They may be better measurers of how well the entire RDT&E acquisition process is working.
- A better measure of S&T is how well is Navy S&T addressing current and future Navy needs, and how prepared is the workforce to address those needs.



III. Assertions – what we believe

1. In-House S&T has great value to the Naval Enterprise.
2. The level of S&T required to support the Navy is independent of the number of ships or sailors. Rather it depends only on what technologies are deployed and what might be needed in the future.
3. It is clear that the Navy wants the benefits of new S&T. (...at a “reasonable” cost)
4. Low hanging S&T “fruit” is a myth.
5. The loss of institutional technical competence leads to failure.
6. S&T projects never go according to plan.

The validity of these “beliefs” will be examined and supported in this presentation.



III. Assertions

1. In-House S&T has great value to the Naval Enterprise.

Value Statements

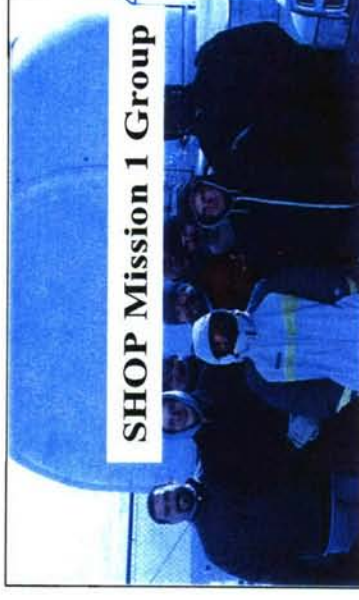
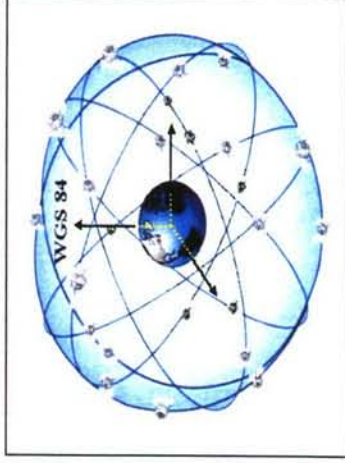
1. In-house S&T enables the recruiting, training, and retention of a technically competent scientific and engineering workforce.
2. Real-time connections between S&T Workforce and acquisition programs enables focused technology for the warfighters.
3. The in-house workforce is highly responsive because of it's ability to innovate and it's knowledge of Navy systems.
4. Long term continuity of experience is essential and can be assured because of flexibility – due to the proximity of technical acquisition responsibilities - in the ability to provide continued support for the technical experts.
5. The S&T trained workforce, by its nature, is agile and adaptive, bringing vision and innovation to future Naval capabilities.
6. Practical applications of new and emerging science and technologies can be focused to support Fleet needs.
7. The in-house S&T- trained workforce is able to anticipate and provide the capabilities to stay ahead of future threats; and reduce many dimensions of risk.



III. Assertions

1. In-House S&T has great value to the Naval Enterprise.

Summary: Metrics can be gathered that support these seven statements.



In Appendix B of this brief we propose specific metrics to be collected for each of these seven values.



III. Assertions

2. The level of S&T required to support the Navy is independent of the number of ships or sailors. Rather it depends only on what technologies are deployed and what might be needed in the future.

Unlike some supporting elements, like e.g. logistics, which depends on the number of ships and sailors at sea, the Navy S&T workforce which is needed is only dependent on the technologies currently in the fleet and the future technologies being prepared.

S&T demonstrates that a capability is feasible – i.e. how to achieve it – and then the production phase goes into action and produces it in the needed quantities.

The S&T is the same for 1 or 100 ships.



E.g.: Targeting software can be reproduced for many ships, but the developing workforce is the same for all or for one.



III. Assertions

3. It is clear that the Navy wants the benefit of new S&T.

This statement can be supported by looking at what the Navy is actually doing.

NAVAIR Advanced Technology Review Boards (ATRB) for Weapons (the first, 1998), Strike Systems, AASW, Common Systems, UAV, Assault and Special Systems, and Carriers.

Gun and Projectile Technology Investment Board – 1999

Office of Submarine Technology – 10 July 1997

SUBTECH – 1997

SURFTECH – July 2002

CARTECH – July 2003

ASW Technology Selection Process – Sep 2004

AEGIS Technology Review Board – late 1980s.

Congress is also interested

“We need a lot more Silver Foxes.”

Adm. Vern Clark. CNO

Subtitle D—Other Matters

SEC. 241. ANNUAL REPORT ON SUBMARINE TECHNOLOGY INSERTION.

(a) **REPORT REQUIRED.**—(1) For each of fiscal years 2006, 2007, 2008, and 2009, the Secretary of Defense shall submit to the congressional defense committees a report on the submarine technologies that are available or potentially available for insertion in submarines of the Navy to reduce the production and operating costs of the submarines while maintaining or improving the effectiveness of the submarines.


(2) The annual report for a fiscal year under paragraph (1) shall be submitted at the same time that the President submits to Congress the budget for that fiscal year under section 1105(a) of title 31, United States Code.

(b) **CONTENT.**—The report on submarine technologies under subsection (a) shall include, for each class of submarines of the Navy, the following matters:

(1) A list of the technologies that have been demonstrated, together with

(A) a plan for the insertion of any such technologies that have been determined appropriate for such submarines; and
(B) the estimated cost of such technology insertions.

(2) A list of the technologies that have not been demonstrated, together with a plan for the demonstration of any such technologies that have the potential for being appropriate for such submarines.



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CARTECH: Charter signed 24 July 2003. The process actually began in the Jan 03 timeframe...but not documented like the charter. Ref. Gary Smith, SPA.

SURFTEC dates from Betsy Delong

SUBTECH dates from a history chart provided by Mark Winters, SPA.
Robin Staton provided the ATRB, GPTIB, ASW Tech, and AEGIS dates.

CNO to the ONR sponsored Naval Industry Research and Development Partnership Conference – Aug 9 2004 – Defense News.



III. Assertions

3. It is clear that the Navy wants the benefits of NEW S&T. Cont.

National Military Strategy – 2004

3. *Technology Diffusion and Access*

Global proliferation of a wide range of technology and weaponry will affect the character of future conflict. Dual-use civilian technologies, especially information technologies, high-resolution imagery and global positioning systems are widely available. These relatively low cost, commercially available technologies will improve the disruptive and destructive capabilities of a wide range of state and non-state actors. Advances in automation and information processing will allow some adversaries to locate and attack targets both overseas and in the United States. Software tools for network-attack, intrusion and disruption are globally available over the Internet, providing almost any interested adversary a basic computer network exploitation or attack capability. Access to advanced weapons systems and innovative delivery systems could fundamentally change warfighting and dramatically increase an adversary's ability to threaten the United States.

Technology diffusion and access to advanced weapons and delivery systems have significant implications for military capabilities. The United States must have the ability to deny adversaries such disruptive technologies and weapons. However, the Armed Forces cannot focus solely on these threats and assume there are not other challenges on the horizon. **Ensuring current readiness while continuing to transform and maintaining unchanged military superiority will require investment.** These are not mutually exclusive goals. The Armed Forces must remain ready to fight even as they transform and transform even as they fight. Adopting an "in-stride" approach to transformation – through rapid prototyping, field experimentation, organizational redesign and concept development – will ensure US military superiority remains unmatched. Such an approach requires effective balancing of resources to **recapitalize critical capabilities and modernize some elements of the force to maintain readiness while investing in programs that extend US military advantages into the future.**



III. Assertions

3. It is clear that the Navy wants the benefits of new S&T. cont.

Summary statement: If you want the benefits of S&T, maintain the technical capacity to recognize, understand, and use S&T products.

- a. History shows us that interrupting the technical base can have devastating long term consequences. E.g. **The Dark Ages; Exodus of scientists from Russia after 1917; The exodus of scientists from Germany in the 1930s; ERGM program; Space Shuttle program; Standard missile program.** (see Appendix D and Assertion #5)
- b. Technical competence requires technical tasking.
For a Warfare Center, as well as for a contractor, skills mix is a result of funded work. It cannot be externally forced in the absence of work. It is not a "procurement" problem. S&T competence is not a commodity.



III. Assertions

4. Low hanging S&T “fruit” is a myth.

New capabilities do not happen overnight. There are usually years of step-by-step progress, including workforce enlightenment, that enable breakthroughs.

“Research on satellites and a global positioning system began in 1946 after the publication of an article on geo-stationary orbits by physicist Arthur C. Clarke, more widely known for writing *2001: A Space Odyssey*. The first GPS satellite was launched in 1978, with the full 24-satellite constellation completed on 9 March 1994“ ... “However, in today’s fast-paced and dynamic environment, the Department of Defense cannot afford 48 years to research, develop, and deploy critical technologies to the warfighter.” *



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*Fountain, page 41



4. Low hanging S&T “fruit” is a myth.

Thermobarics


Delivered in < 6 months

III. Assertions



*30 years of basic chemistry
yields combat options*

28 January 2005




4. Low hanging S&T “fruit” is a myth.


Thermobarics

Delivered in < 6 months


III. Assertions



DTRA test 118B
14 Dec 01



BLU 118B at NSWCI-IH



Afghanistan—cave complexes struck 3 Mar 02

30 years of basic chemistry yields combat options

28 January 2005

Accidents show part of the motivation: you want propellants to burn reliably and explosives to detonate violently, but only at the right place and the right time. On 29 July 1967, a Zuni rocket loaded aboard an A-4 Skyhawk on USS Forrestal's flight deck cooked off and struck the aircraft to its front (whose pilot was the future Senator McCain). 134 died in the fires and explosions. USS Enterprise and USS Nimitz later suffered similar accidents. ONR's program in synthetic organic chemistry addressed basic problems underlying the accidents. Energetic materials (propellants and explosives) must meet conflicting performance demands:

- They must release large amounts of energy rapidly and reliably
- They must be safe to handle—they must resist mechanical shock, high temperatures, etc.
- They must be safe to store for 20 years or more

Energetic materials are difficult to characterize. Most of the work had been empirical—even Edisonian—trial and error. This means that developing new explosives and propellants with desirable characteristics has been slow, expensive, and suboptimal.

The challenge is to understand the chemical reactions sufficiently to eliminate the trial-and-error empiricism of development and monitoring.

Explosives are *composites*, so local effects cannot be ignored, and the chemical reactions are *fast*. Basic research has been necessary in: *energetic crystal structures*, *combustion mechanisms*, and *initiation mechanisms*. Performers included University of Chicago, University of New Orleans, City University of New York, MIT, Stevens Institute of Technology, Cal Tech, and NSWC Indian Head. Among ONR's performers in this work was Ahmed Zewail of Cal Tech, whose development of femtochemistry enabled chemists to observe fast reactions as they occur. Zewail's work earned him the 1999 Nobel Prize for Chemistry.

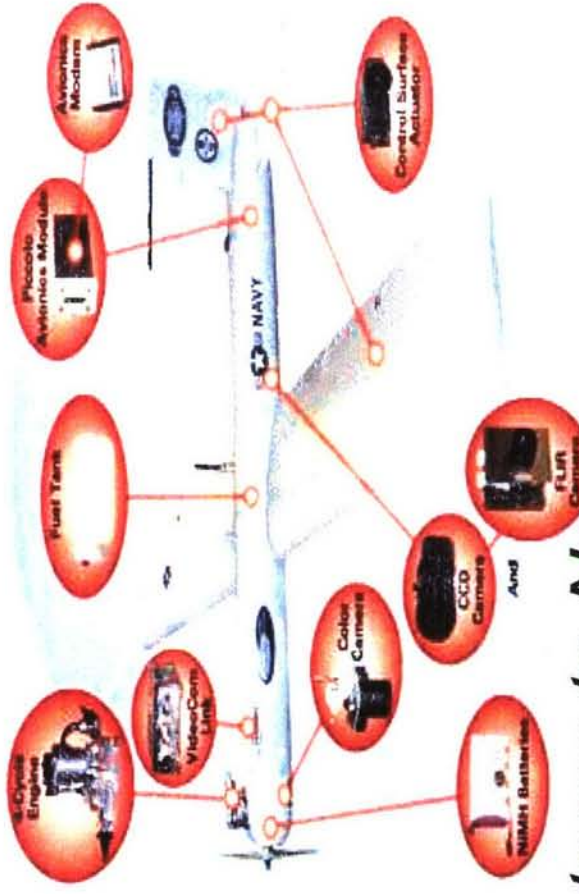
This basic research ultimately transitioned to Naval Surface Warfare Center Indian Head's work on thermobarics. After 9/11, OSD called for thermobarics (on 19 Sep). Indian Head's thermobaric fill was weaponized and tested by DTRA, and used operationally against al Qaeda cave sanctuaries in Gardez, Afghanistan on 3 Mar 02.



Silver Fox:
Robot takes point


4. Low hanging S&T “fruit”
is a myth.

III. Assertions



Navy SBIR delivers 8 systems to Navy
Special Operations in 60 days. 18 systems
currently deployed to CENTCOM.

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Silver Fox:

Robot takes point

4. Low hanging S&T “fruit” is a myth.

III. Assertions

Navy SBIR delivers 8 systems to Navy Special Operations in 60 days. 18 systems currently deployed to CENTCOM.

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Initially fielded with I MEF, then transferred to SEALs. ONR SBIR performer Advanced Ceramics delivered 8 systems in 60 days, with ONR military operators. 18 Silver Foxes were deployed within CENTCOM in 2003.

Spiral development yielded quick operational roll-outs and continuing improvements. Rapid prototyping and insertion of technical innovations into subsequent blocks have enabled the system to respond to emergent needs. Its per unit cost of \$26K is approaching commoditization, and 70% of that cost is the EO/avionics suite.

Current endurance is 3 to 5 hours. Flight controls use waypoint navigation with a manual override. The vehicle may be launched either autonomously from a catapult (see the picture on the left, above) or manually from the ground or a vehicle. The system is recovered manually, with autonomous recovery coming in near future blocks. The engine burns model airplane fuel, with future engines to burn diesel and JP-5/8+oil.

Multiple UAVs may be controlled as a swarm from a laptop computer with complete FalconView user interface and mission planning features. Sensors include EO cameras (low-res color and high-res low light capability) and a FLIR camera (320x240 microbolometer). The control data link is a line-of-sight spread spectrum system demonstrated to 20nm. The video data link, also line-of-sight, has also been demonstrated to 20nm.



III. Assertions

4. Low hanging S&T “fruit” is a myth.

Early Unmanned Vehicle Research

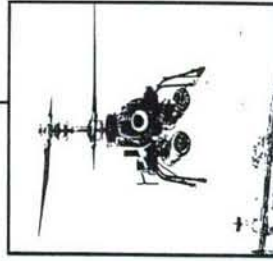
A flying bomb (N9 aircraft) is tested atop a Marmon automobile in 1918 to observe its functioning at flight speed. This was an early unmanned vehicle.



AN AUTOMOBILE IS SUBSTITUTED FOR A WIND TUNNEL IN A TEST OF A FLYING BOMB

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ALSO: As the military and industry look forward to the day when unmanned aerial vehicles will be used in large numbers for tactical purposes, it is worth noting that the U.S. Navy had large numbers of a weapons-carrying tactical operational UAV more than 40 years ago. The Navy in 1958 contracted with the Gyrodyne Corporation of Long Island, NY, to build the DSN-1, an armed version of Gyrodyne's YRON-1 helicopter. Gyrodyne, founded in 1946 by Peter Papadakos called the YRON-1 the “ultra-lightweight rotocycle”, a rotary-wing aircraft designed to get a single man aloft for observation and targeting.





III. Assertions

5. The loss of institutional technical competence leads to failure.

The government's primary requisite is to be effective and efficient. In war it is useless to lose at half the cost it would take to win. *

In 1940 President Roosevelt was persuaded by Vannevar Bush to establish a National Defense Research Committee to improve American scientific preparedness for war. Bush's philosophy for the new organization was his belief that "know-how" could be "acquired only by constant research" and that the quantity of research was as important as the quality in obtaining quick answers to questions about such things as the design of new aircraft. **



III. Assertions

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Colvard – "Savings can have a high price". Nov 1998. Govexec.com Magazine.

** Laboratory Warriors, pg 115. Vannevar Bush was the President of the Carnegie Institution at the time, and was Chairman of the national Advisory Committee on Aeronautics.



III. Assertions

5. The loss of institutional technical competence leads to failure.

“In the technically complex world of defense, the inherently governmental functions encompass more than just policy decisions about force structure and missions. They require three key elements:

Government employees

- who can understand military problems in technical terms,
- who know someone potentially capable of solving them and
- who can recognize valid technical solutions.

“The government should promote research and development in its laboratories and centers to help employees understand technology that could be used to solve military problems.

The military program managers who deal with the private sector on engineering development need this knowledge to weigh acquisition decisions. The government should keep enough internal work to sustain its technical capability.” (Colvard -)



III. Assertions

5. The loss of institutional technical competence leads to failure. CONT.

“Historical evidence proves there are serious consequences when technical capability is lost or technical advice ignored”.(Colvard)
e.g.:

- ValuJet lost technical control of its fleet and was grounded after one of its jets crashed in the Florida Everglades in 1996
- NASA decided to go through with the doomed Challenger launch in 1986, despite technical advice to delay it because of cold weather's effects on the space shuttle's O-rings.
- The Navy lost its surface-launched missile engineering capability, at least for the short term, in a defense industry shakeout that followed the Cold War.

VDOT Experience – Too much contracted out. Not enough experience remained on the state team- led to project failure. Commissioner Shucet turning it around:...”ordered the hiring of 50 licensed professional engineers to work in the districts.”



III. Assertions

5. The loss of institutional technical competence leads to failure. CONT.

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Colvard – “Savings can have a high price.”

VDOT – Aug 2003, VDOT Official Dismissed.



III. Assertions

5. The loss of institutional technical competence leads to failure. CONT

The recent NASA Space Shuttle experience. Too much contracted out. —” the leader of the mission management team at Johnson Space Center, Linda Ham, said in her meeting with reporters last month that she had considered whether debris shed on liftoff, now believed to be the fatal flaw, could have damaged the orbiter. But she said she had relied on an analysis by Boeing that indicated no threat to the mission from the impact of the foam.

"We must rely on our contractor work force who had the systems expertise to go off and do that analysis," she told reporters last month. "We don't have the tools to do that. We don't have the knowledge to do that or the background or expertise to do that kind of thing."



III. Assertions

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“Shuttle Inquiry Uncovers Flaws...”



III. Assertions

5. The loss of institutional technical competence leads to failure. CONT

Report: Boeing "brain drain" linked to Columbia accident
Posted: Thu, Jul 31, 2003, 7:24 PM ET (2324 GMT)

"A loss of hundreds of highly-trained engineers when Boeing moved offices two years ago may have played a role in the Columbia accident, the Los Angeles Times reported Thursday. In 2001 Boeing shifted space shuttle engineering offices from California to Texas, but about 80% of the 500 employees in California refused to move, forcing Boeing to hire new employees, including many engineers, in Texas. The STS-107 mission was the first time the new Texas office has primary responsibility for the shuttle flight. Engineers who remained behind in California told the Times that they believe that they would have reached a different conclusion about the damage the foam impact caused to the shuttle, although their primary concern was about damage to foam, not the reinforced carbon-carbon leading edge panels. Boeing officials, while acknowledging that they did lose some experienced engineers in the move, say moving the office closer to the Johnson Space Center resulted in a stronger team."



III. Assertions

Mars Climate Orbiter Mission Failure – Sep 1999

From the final report:

Root Cause: Failure to use metric units in the coding of a ground software file, “Small Forces,” used in trajectory models.

Contributing Causes:

1. Undetected mismodeling of spacecraft velocity changes
2. Navigation Team unfamiliar with spacecraft
3. Trajectory correction maneuver number 5 not performed
4. System engineering process did not adequately address transition from development to operations
5. Inadequate communications between project elements
6. Inadequate operations Navigation Team staffing
7. Inadequate training
8. Verification and validation process did not adequately address ground software



III. Assertions

5. The loss of institutional technical competence leads to failure. CONT

“The Navy can never contract out its ability to: understand military problems in technical terms; know who has the potential to solve those problems; and be able to verify a correct solution technically when it is presented.”

“Further, military preparedness is a continuous function. The retained intellectual residuals from investment in the Navy's science and technology infrastructure are available on demand to the Navy. Knowledge and experience gained through a contract operation may well be lost when the contract ends or goes to another contractor. It is appropriate within our free enterprise system that the continuous function is in-house and the discontinuous one is in industry. It takes a well-thought association of the two both to decide on and to provide material the Navy needs. “



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Colvard – “Closing the science-sailor gap”



III. Assertions

5. The loss of institutional technical competence leads to failure. CONT

“Coupled with downsizing, the mergers within the defense industrial base have eliminated the competitive market in defense. This requires the Navy to be an even more technically competent buyer. Private industry is in no position to define missions, analyze requirements, and maintain the Navy's technical safety net. If the Navy loses its effective internal science and technology structure, just when it needs it most, it never will regain it, short of a catastrophic normative reset. “*

“I believe Technical Authority is the most important thing we do.”

VADM Phillip M. Balisle, COMNAVSEA



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28 January 2005

* Colvard – “Closing the science-sailor gap” – June 2002 – Naval Institute Proceedings.

Balisle quote from the briefing on NAVSEA Systems Engineering and Technical Authority, 15-16 July 2004, by

Captain Steve Metz
Assistant for Fleet Naval Engineering and Maintenance Process Improvement
SEA 05N
(202) 781-3575
metzsd@navsea.navy.mil



III. Assertions

5. The loss of institutional technical competence leads to failure. CONT

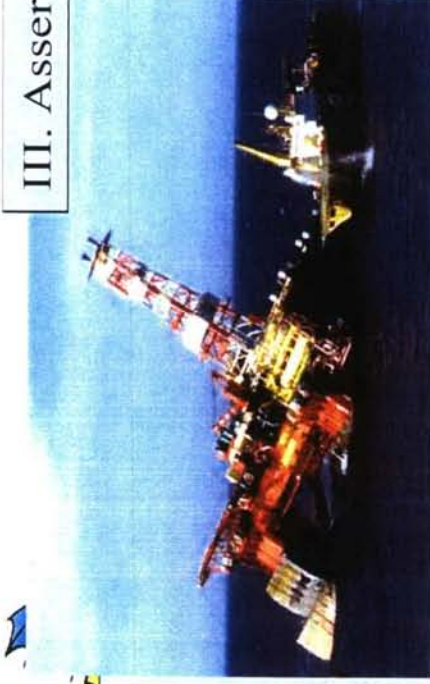
"Here the cause of research is close to the hearts of man. It is staffed by civilian scientists and officers of the Navy. Those men know, far better than any of us, that the results of research cannot be placed on a time schedule, that the ideas of men of genius must have time and leisure in which to flower. They know far better than any of us that the dollars invested in research in times of peace may mean the life of the nation when it goes to war."

Navy Secretary James Forrestal
July 1943

"My goal is to ensure that we're putting our resources where we maximize our war fighting capability. My belief is that the navy is all about credible combat power in the far corners of the earth, period. That's what this is about."

Admiral Vern Clark Remarks, 7th Annual Navy/CEO Conference, November 6, 2001

III. Assertions



"Petrobras has established new global benchmarks for the generation of exceptional shareholder wealth through an aggressive and innovative programme of cost cutting on its P36 production facility. Conventional constraints have been successfully challenged and replaced with new paradigms appropriate to the globalised corporate market place.

Through an integrated network of facilitated workshops, the project successfully rejected the established constricting and negative influences of prescriptive engineering, onerous quality requirements, and outdated concepts of inspection and client control.

Elimination of these unnecessary straitjackets has empowered the project's suppliers and contractors to propose highly economical solutions, with the win-win bonus of enhanced profitability margins for themselves.

The P36 platform shows the shape of things to come in unregulated global market economy of the 21st Century." (a Petrobras executive)



5. The loss of institutional technical competence leads to failure. CONT



III. Assertions

5. The loss of institutional technical competence leads to failure.

Summary:

President Harry Truman: "No aspect of military preparedness is more important than scientific research."



S&T today ensures future workforce competence

See Appendix D for more examples



III. Assertions

6. S&T projects never go according to plan.

July 1943 - "Here the cause of research is close to the hearts of man. It is staffed by civilian scientists and officers of the Navy. Those men know, far better than any of us, that the results of research cannot be placed on a time schedule, that the ideas of men of genius must have time and leisure in which to flower. They know far better than any of us that the dollars invested in research in times of peace may mean the life of the nation when it goes to war."

James Forrestal, Secretary of the Navy.





III. Assertions

6. S&T projects never go according to plan. Cont.

Example: FNC projects, where a high level of initial planning occurred, but the transitions have been no better than with the former program structure, and significant resources are wasted in the stop/start “churn”.*

Because (1) it is impossible to predict when a solution will occur. (2) the Program Manager has to be convinced that the technology will solve his problem (3) ..on his schedule (4) when he has the dollars available and the priority is there to apply the transition dollars...

Acquisition and operational managers normally focus on current issues, not what the future will need.



III. Assertions

**6. S&T projects never go according to plan.
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* For this analysis see: “An Examination of the NAVY’S Future Naval Capability Technology Transition Process” by Robert E. McGahern , September 2004. Naval PG School Thesis.



IV. S&T Metrics should be collected in response to specific questions from “evaluators”. Several questions are proposed that might be of interest at all levels of management.

CNO: What is the benefit to the Navy from \$2B annual TOA in Navy S&T accounts?

What is the benefit to the Navy from the government and contractor workyears devoted to management, identification, or development of S&T products?

CNR: How well is my S&T money addressing Navy Technical Needs?

What is the quality of Navy S&T compared to all other S&T?

NAVSEA: How do S&T people and funding support the NAVSEA Technical Authority responsibilities?

NSWC: How does S&T help meet PAD current and future responsibilities?

DD CO: Are my S&T demographics in line with PAD and Technical Pyramid needs?
What is the health of the Dahlgren Division S&T program?

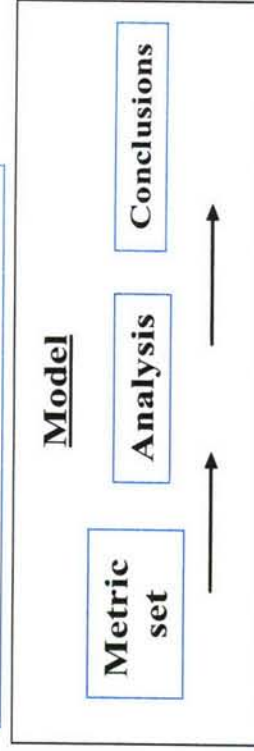
DD S&T Director: Do my S&T projects address PAD and other DoD needs?



IV. S&T Metrics – Health Indicators

- **Annual Budget** – ONR Discretionary, *Internal Discretionary*, and Other
- # S&T Funded Scientists and Engineers
- Navy S&T Budget Request
- Navy S&T Appropriated
- **S&E Demographics** (green)
- # Proposals submitted and endorsed
- **Transitions**
- Patents
- CRADAs
- Patent Disclosures
- PAD needs addressed (green)
- Pillar alignment (green)
- S&E attrition rate- total, by discipline, training category
- Publications, awards,
- **Capability Gap Coverage** (green)
- **ROI**

Blue are manageable –
i.e. within our control.
Green – Immediate
output
Red – long term outcomes
Black – out of our control





V. Potential metrics. Metric Data collection is not a trivial enterprise.

“Presently there is no widely accepted way for the federal government in conjunction with the scientific community to make priority decisions about the allocation of resources in and across scientific disciplines. While metrics such as the number and quality of peer-reviewed publications, citations, graduate students, research awards, and the level of external funding are indicators of a vibrant research program, they do not necessarily show how the needs of the warfighter are being met. Without meaningful and practical output measures, the system of peer-reviewed individual research grants and institutional grants simply invests in the infrastructure and salaries necessary for researchers to do their work. The scientific work that proceeds from these investments should therefore meet some metric to ensure that the joint warfighting capabilities of the future are being developed.” (Fountain, pg 45)



V. Potential metrics. Metric Data collection is not a trivial enterprise.

Here are some attributes to be considered:

John H. Hopps, Jr., Deputy Director of Defense Research and Engineering, and Deputy Undersecretary of Defense in the Department of Defense, has stated that our “defense laboratories should have the same attributes as our transformed uniformed military forces.” While the DOD is transforming to build modular joint forces with the attributes of speed, agility, lethality, and knowledge, **the service laboratories need to transform with the parallel attributes of “productivity; responsiveness and adaptability; relevance, programming, and execution; generation and application; and perpetuation of knowledge.”** Hopps argues that this transformation should lead to a greater investment in breakthrough activities and increase the reach of the defense labs into university basic research programs.³⁰ *

“Peer Review is the Sacred Cow of S&T Metrics.”**



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*Fountain, page 47/48

** The Metrics of Science and Technology”, Geisler.



V. Potential metrics. What you measure is what you will get.

Summary: Appendix B presents some potential measures for the seven value statements on slide 29.



VI. Conclusions

- Metrics can supply evidence that the basic S&T assertions in this brief are relevant.
- S&T metrics can be defined and collected in response to specific questions, but you tend to get what you choose to measure.
- The immediate ROI for Navy S&T is its contribution to the quality and development of “our people, (*who*) will determine our future success”*...or failure.
- Transitions and speed-of-transition are not significant measures of S&T performance. They may be better measures of how well the entire RDT&E acquisition process is working.
- A better measure of S&T is how well is Navy S&T addressing current and future Navy needs, and how prepared is the workforce to address those needs.
- The size of the Navy S&T budget and in-house workforce should be determined by what you want it to do, I.e. what Navy capabilities need to be enabled.



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28 January 2005

* This is from the 2005 CNO Guidance Playbook, page 3, Guiding Principal #12.



Appendix A: How Much is Enough?

S&T Workforce Estimation

During WW I the American Chemical Society offered to supply chemists to the Army. The Army replied, “Thank you very much, but we already have a chemist”. *

“...when (Robert) Millikan (1930s) offered the services of the National Research Council to a conference of generals, the assistant chief of staff for supply implied that there was little need for scientists to dream up new weapons or to suggest ways to use scientific breakthroughs- those matters would be handled internally by the armed services.” (Laboratory Warriors – pg 26)

Does this mindset still exist?



Appendix A: How Much is Enough?

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28 January 2005

*Jim Colvard paper – * “Why Navy Laboratories?”, Jim Colvard:
<http://www.nstarweb.com/whynavylab.pdf>

** “Laboratory Warriors”, page 26.



Algorithm Principle

We include here an algorithm for estimating the size of the S&T workforce. This is an *estimate*. The question “How much is enough?” is perhaps subjective. This algorithm will suggest how much is needed.

**We base the estimate on What we want this workforce to do.
e.g., Close the Naval Capability gaps.**



Workforce Algorithm

Appendix A

1. S&T Level of Effort :

$$N_{\text{people}} = (1 + \text{Pover}) * N_{\text{s\&t}}$$

$$N_{\text{s\&t}} = N_{\text{p/a}} * N_{\text{a}} * N_{\text{g}} * (N_{\text{s}} + N_{\text{e}})$$

NAVSEA Pyramid Support :

$$N_{\text{whp}} = N_{\text{wh}} * N_{\text{avgwhp}} * P_{\text{ps\&t}} * (1 - \text{Poverlap})$$

3. Infrastructure Cost:

$$C_{\text{infra}} = n * (N_{\text{people}} + N_{\text{whp}}) * WY$$

4. Total = N total = 1 + 2 is number of people.

Cost is 3 + cost of people.

Questions: Is everything covered here?
Can the parameters be estimated?
Should we separate 6.1, 6.2, and 6.3?
How to validate this?



What we need to know for this algorithm

(Bold are calculated)

- Ng = Number of Naval Capability Gaps
- Na = Number of approaches per Gap
- Np/a = Number of projects per approach
- **Nproj = Number of annual projects**
- Ns = number of scientists per project
- Ne = Number of engineers per project
- **Ns&t = S&E staffing level for Ng Gaps**
- Pover = fractional overhead
- **Npeople = adjusted number of people supporting Ng Gaps**
- n = personnel cost multiple, >= 1
- WY = consolidated work year rate
- **Cpeople = total people cost**
- **Cinfra = annual infrastructure cost**
- **Ctotal = total annual cost - infrastructure plus people**
- Nwh = number of warrant holders
- Pps&t is the fraction of the pyramid that is S&T trained
- Navgwhp= average number of people in a technical pyramid
- Poverlap = fractional overlap between pyramids and Gaps
- **Nwhp = number of Warrant Holders support people**
- **Ntotal = total S&T workforce people**



Appendix A

Sample Calculations

<u>Parameters</u>	<u>Case 1</u>	<u>Case 2</u>	<u>Case 3</u>	<u>Case 4</u>	<u>Case 5</u>	<u>Case 6</u>
Ng	100	100	75	100	75	100
Na	2	2	2	2	2	2
Np/a	3	3	3	3	3	4
Nproj	600	600	450	600	450	800
Ns	2	2	2	2	2	2
Ne	2	3	2	2	3	2
Ns&t	2400	3000	1800	2400	2250	3200
Pover	0.1	0.1	0.1	0.1	0.1	0.05
n	1	1	1	1	1	1
WY	150,000	150,000	150,000	150,000	150,000	150,000
P%infra	0.1	0.1	0.1	0.1	0.1	0.1
Cpeople	\$711,630,000	\$810,630,000	\$612,630,000	\$756,720,000	\$731,970,000	\$909,810,000
Cinfra	\$71,163,000	\$81,063,000	\$61,263,000	\$75,672,000	\$73,197,000	\$90,981,000
Ctotal	\$782,793,000	\$891,693,000	\$673,893,000	\$832,392,000	\$805,167,000	\$1,000,791,000
Nwh	167	167	167	167	167	167
Navgwhp	60	60	60	60	60	60
Pps&t	0.3	0.3	0.3	0.3	0.3	0.3
Poverlap	0.3	0.3	0.3	0.2	0.2	0.1
Nwhp	2104	2104	2104	2405	2405	2705
Npeople	2640	3300	1980	2640	2475	3360
*percentage	1.45%	1.81%	1.09%	1.45%	1.36%	1.85%
Ntotal	4744	5404	4084	5045	4880	6065
*percentage	2.61%	2.97%	2.25%	2.77%	2.68%	3.33%

*Percentages are of the FY 03 Navy civilian workforce of 181,902



Validation: Comparison numbers

1. “S&T supports about 4000 Navy people at least half time”.(1)
2. DSB – 1998 Task Force, suggests 3.5% of TOA is reasonable. This would be **6367** people*.
3. The DSB 2002 study suggests 3.0% of TOA is fine. This would be **5457** people.
4. Roosevelt’s Scientific Advisory Board advised (circa 1934) that the then-current rate of investment was inadequate: less than 2%.**(2)
This would be **3638** people today.
5. **Public Sector Innovation Working Group recommended 1% of GDP for DoD, NSF, and DOE(3). 2004 GDP was \$11,733.5 B**

* Based on 2003: 181,902 Navy civilians)



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28 January 2005

(1) Dr. McDuffie.

(2) ** "Laboratory Warriors", page 63.

(3) National Innovation Initiative – Public Sector Innovation Working Group Report (date received – 8 Mar 2005, no date shown on the report.)
http://www.compete.org/docs/pdf/NII_Public_Sector_Final%20Report.pdf



DSB 1998 Task Force on Defense S&T Base for the 21st Century

Summary Observations:

The observations concerning the topic of S&T funding level and its determination can be summarized as follows:

- DOD S&T is vital to the future of U. S. Military balance of power. Over the past century, technical developments funded by the military have had an enormous impact on military capabilities and have been decisive in the outcome of conflicts.
- No formulas for establishing S&T funding have been discovered either in government agencies or in industry. An analytic framework for establishing R&D funding can be formulated, but the coefficients of the equation terms are not known at this time.
- Industrial R&D funding (including the research or S&T component) tends to be set in meetings of the CEO, CFO, CTO, and senior vice presidents.
- Industrial decisions on S&T funding are influenced by the potential return on investment, competitiveness, and strategic objectives.
- Industrial R&D is growing relative to DOD but it is predominantly short term focus.
- Current DOD S&T funding (about 2.9% of total DOD funding) is somewhat less than the practice of those high-technology industries which are dependent on technology supremacy or patent monopolies for commercial success. (*FY-2004 for Navy was 1.5% - next chart*)
- Lower levels of DOD S&T funding could threaten future (20 years and beyond) dominance of U. S. military forces.
- Continuity of S&T funding level is thought important in most industries (to prevent disruption of programs and research teams).
- One third of industry research is typically exploratory and focused on revolutionary technologies whereas two-thirds is focused on evolutionary improvements in identified product needs.



Appendix A

This is data on Navy TOA and Navy S&T

	FY-04 Navy R&D Budgets (000K)			
	02	03	04	05
Research, Development, Test & Eval, Navy 15,444,110		11,379,389	13,630,517	14,106,653
Basic Research	394,837	412,322	456,586	471,811
Applied Research	755,239	805,709	535,943	600,674
Advanced Technology Development	847,495	813,228	721,773	777,579
total S&T	1,997,571	2,031,259	1,714,302	1,850,064
% RDT&E	.18	.15	.12	.12

http://www.dod.mil/comptroller/defbudget/fy2004/fy2004_greenbook.pdf

/FY- Year/	01	02	03	04
Navy TOA \$millions Current \$	96,117 3%=2,883	101,778 3%=3,053 2% = 2036	111,184 3%=3,336 1.8% = 2,001	114,720 3%=3,442 1.5% = 1,721



ILIR Data

28 January 2005



Wayne, The numbers you are referring to were produced by Gary Hess
 email: hessgm@navsea.navy.mil; work phone: +1 (202) 781-3441) Feel free
 to contact him with your specific questions regarding those numbers.

Best regards,
 --Ernest

ILIR data

Output	1993	1994	1995	1996	1997	1998	1999	2000	2001
# "Transitions"	No Data	38	35	41	33	38	44	49	50
# Projects (~# PIs, not FTEs)	181	197	218	214	206	192	183	195	198
Published Papers	393	270	259	225	250	261	270	202	203
Submitted Papers	110	90	82	74	59	17	19	54	109
Books/Chapters	52	7	20	19	6	8	13	16	8
Patents/Patent Applications	79	67	69	72	93	98	99	105	94
Government Reports	76	62	68	56	38	27	20	8	19
Dissertations	37	10	13	5	3	1	6	5	3
Presentations	417	259	369	248	248	234	234	229	220
Awards/Honors	79	52	68	39	41	39	48	19	14
Funding (M)	\$15.4	\$16.8	\$17.0	\$15.0	\$13.7	\$13.1	\$13.0	\$14.2	\$14.4



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28 January 2005

From Kavetsky brief to B Dept Offsite – Dec 2004.

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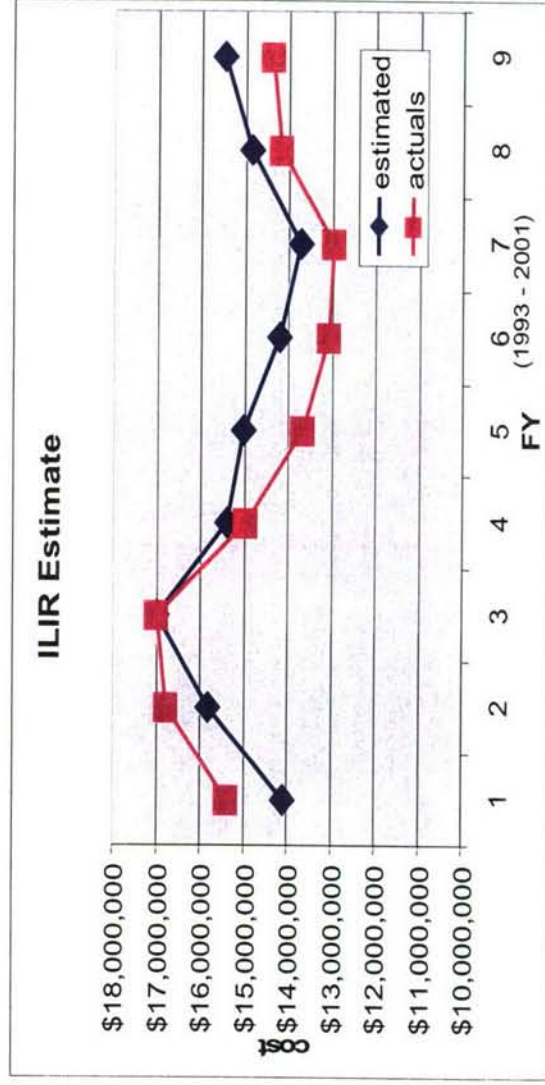
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	1993	1994	1995	1996	1997	1998	1999	2000
Cpeople-est	\$14,109,312	\$15,836,436	\$17,023,882	\$15,415,704	\$15,054,480	\$14,231,808	\$13,755,744	\$14,861,340
actuals	\$15,400,000	\$16,800,000	\$17,000,000	\$15,000,000	\$13,700,000	\$13,100,000	\$13,000,000	\$14,200,000

Parameters	1993
Ng	181
Na	1
Np/a	1
Nproj	181
Ns	0.7
Ne	0
Ns&t	126.7
Pover	
n	0
WY	111,360
P%infra	0.1
Cpeople	\$14,109,312
Cinfra	\$0
Ctotal	\$14,109,312



Note: I did a parameter adjustment at years 1, 2, and 3. Assumption was that there was more money per project in these early years. W.H.



Afterthoughts

1. **One improvement might be to separate out the 6.1 Basic Research. The 6.2 and 6.3 activities are more directly related to Capability Gaps. But then we would have to decide what we want the 6.1 work force to do.**
2. **Another refinement would be to consider each category separately because in general the projects become larger from 6.1 to 6.3.**
3. **A better estimate of the current S&T workforce should be obtainable.**
4. **The labor rates between 1993 and 2001 were taken from Dahlgren data – and probably do not represent well all Navy lab participants in ILIR.**



Appendix B: Metrics for our Value Statements.

28 January 2005



Metrics for:

Appendix B

1. In-house S&T enables the recruiting, training, and retention of a Technically competent scientific and engineering workforce.

- Distribution of S&T disciplines across all technical pyramids.
- Specialty areas support all PADS and Warrant Holders.
- NFFTI, D&I, FNC, INP program support
- Patents, citations, honors, papers, books—output.
- Improvements in Capability, Force multiplication, Cost Avoidance
- Transitions – technology to acquisition systems, and people go with them.
- Amount of S&T training
- Training required
- Training throughput

1/12/2005
13 Decemb er 2004

6th try - S&T Metrics

57



Metrics for:

Appendix B

3. The in-house workforce is highly responsive because of it's ability to innovate and it's knowledge of Navy systems.

- Number of requests for help
- Number of warfighter capability gaps recognized
- Number of solutions provided
- Sponsor/PMs recognition
- Demographics
- Number of S&T projects proposed per Gap

1/12/2005
13 Decemb er 2004

6th try - S&T Metrics

59



Metrics for:

Appendix B

2. Real-time connections between S&T Workforce and acquisition programs enables focused technology for the warfighters.

Systems that provide needed Navy capabilities for desired operational effects

Interactions with Acquisition Programs

Risk reduction throughout the acquisition process

Research areas endorsed by PMs.

Funding support from PMs

Internal investment focus on acquisition programs

1/12/2005
13 Decemb er 2004

6th try - S&T Metrics

58



Metrics for:

Appendix B


4. Long term continuity of experience is essential and can be assured because of flexibility – due to the proximity of technical acquisition responsibilities – in the ability to provide continued support for the technical experts.

- Workforce retained in each TA area
- Sustained positive demographics
- Attrition rate constant or decreasing
- Hiring enabled (Interviews)
- Age vs tenure: % > 10 yrs
- Age distribution: avg age
- Risk areas ameliorated
- % overlap with Technical Pyramids
- Number of Technical Pyramids
- Size of Pyramids
- % of Infrastructure

1/12/2005
13 Decemb er 2004

6th try - S&T Metrics

60

 <div>Appendix B</div> <div>Metrics for:</div> <div>5. The S&T trained workforce, by its nature, is agile and adaptive, bringing vision and innovation to future Naval capabilities.</div> <div><div>•Number helping create the vision for the next navy and navy after next.</div><div>•S&T directed at cost reduction, new capabilities, force multiplication – transforming innovations.</div><div>•Specific anecdotal evidence.</div></div> <div>1/12/2005 15 December 2004</div> <div>61</div>	<div>Appendix B</div> <div>Metrics for</div> <div>6. Practical applications of new and emerging science and technologies can be focused to support Fleet needs.</div> <div><div>•Combatant Commander's needs addressed.</div><div>•COCOM and other recognitions</div><div>•% of Gaps supplied by the COCOM</div></div> <div>1/12/2005 15 December 2004</div> <div>62</div>
<div>Appendix B</div> <div>Metrics for</div> <div>7. The in-house S&T- trained workforce is able to anticipate and provide the capabilities to stay ahead of future threats; and reduce many dimensions of risk.</div> <div><div>Risks addressed</div><div>New threats described and understood</div></div> <div>1/12/2005 15 December 2004</div> <div>63</div>	<div>Appendix B</div> <div>Metrics for</div> <div>6. Practical applications of new and emerging science and technologies can be focused to support Fleet needs.</div> <div><div>•Combatant Commander's needs addressed.</div><div>•COCOM and other recognitions</div><div>•% of Gaps supplied by the COCOM</div></div> <div>1/12/2005 15 December 2004</div> <div>62</div>



Appendix C: Historical Examples of Dahlgren products of S&T that have transitioned.

Caution: To show examples trivializes the results of S&T investment. It is too tempting to equate a few bullets with the \$2B annual investment.



Global Positioning System

The first showcase area will be Dahlgren contributions to the Global Positioning System. The Global Positioning System has almost become a household word, at least in its abbreviated form, “GPS”. This position-finding service, coupled with neighborhood and national maps, is now available on automobiles, ships and boats, and even as hand-held devices that fit in one’s pocket or purse. The story of GPS, and the complex science and technology that makes it possible, cannot be told without acknowledging the enabling contributions of critical capabilities here at the Naval Weapons Laboratory at Dahlgren in the 1950s and early 1960s.

In order to aim naval guns accurately, scientists and engineers at Dahlgren developed methods to simulate mathematically the trajectories of gun-fired projectiles, using the very first large electronic computers to solve the equations of motion. While this early use of computers greatly improved the accuracy of Naval guns, bombs, and rockets, it also led to the realization that detailed knowledge of the earth’s gravity was essential to very long range trajectories such as those of the Polaris, Poseidon, and Trident intercontinental ballistic missiles. Modeling earth-orbiting satellites was the next evolution, and thus the ability to very precisely locate satellites led to their use as navigation aids. Scientists at Dahlgren continue today to discover ways to make GPS even more accurate—even to a few centimeters—and furthermore to develop new concepts for using GPS.

GPS Operational Constellation. NSWCDD determines the precise orbits of the satellites, defines the GPS measurement reference frame (WGS 84) and supports the development of GPS applications.

NSWCDD continues to define, and refine, the World Geodetic System (WGS 84) GPS coordinate frame—the frame to which all GPS measurements are referenced. NSWCDD continues to compute the precise GPS satellite orbits and positions of the Air Force and National Imagery and Mapping Agency (NIMA) GPS tracking sites. In addition, NSWCDD is applying recently developed, high-accuracy, real-time dynamic positioning capabilities for Unmanned Aerial Vehicle (UAV) remote sensor navigation and improved target geolocation. Further, NSWCDD continues to support the development of GPS sensors for high dynamics missile applications, GPS guided munitions, 6-degree-of-freedom modeling and guidance simulations, very accurate relative time, and missile defense. NSWCDD scientists and engineers supporting the GPS development aspects of these projects include Everett Swift, James O’Toole, John Carr, Michael Merrigan, Bruce Hermann, Larry Miller, Jim Cunningham, Ernest Ohlmeyer, George Wiles, John Lundberg and Alan Evans.



Remote Detection of Chemical Warfare Agents.

Chemical agents as a threat to ship crews is not a recent discovery. Scientists and engineers at the Dahlgren Division have been aware of this potential problem since the early 1970s. During evaluation of a prototype thermal imaging system for fire control, in support of shore bombardments, they observed that the clouds of dust created by the explosions completely obscured the background for several minutes. The same group had been evaluating an Army long-path infrared sensor designed to remotely detect chemical warfare agents. They hypothesized that the fire control sensor they were testing, an early thermal imager, the AN/AAS-28A, should be able to detect a nerve agent cloud. This observation was successfully tested in 1972 with various non-lethal chemicals, strongly supporting their earlier prediction.

At this point the problem shifted from detection to discrimination. It was necessary to distinguish the commonly seen clouds of dust, and other harmless materials, from a cloud of chemical agent that may actually pose a risk to ships or to amphibious troops, if they were to encounter the cloud. The solution was to add a four-port spectral filter wheel (SFW) just before the detector array. The filters were selected to emphasize the difference between the absorption and emission spectra of nerve agents and normally encountered dust and water. An operator viewing a cloud would rapidly switch from one filter to another and observe the resulting change in the image. By 1978 the feasibility of distinguishing between agent simulants and harmless interferents had been demonstrated.

As frequently happens when a new capability is shown to be feasible, and even demonstrated, the next step of development and production did not happen quickly. In this case, it was four years before this chemical agent sensing equipment could be made ready for production. Inter-service competition caused some of this delay, but factors relating to environmental hardening discovered during the procurement process and inertia within the procurement system itself also contributed. A total of 1,029 AN/KAS-1 units were eventually produced and installed on every ship in the U.S. Navy. As the Navy has reduced in size from 600 to nearer 300 ships, spare units have been diverted to other applications such as special operations, border security and federal law enforcement operations.

(Mr. Roger Horman was a principal developer of this system.)



Automated Cruise Missile Mission Planning.

In 1990, before the Tomahawk Cruise Missile was first fired in conflict, a small group from Dahlgren approached the Office of Naval Research to propose a strike warfare technology project on rapid Tomahawk mission planning. The objective was to compute a full Tomahawk mission in less than 5 minutes. This was viewed by many at the time as an impossible achievement far exceeding any reasonable expectation of what might be a credible result from an ONR investment since this result would be a three orders of magnitude improvement over the contemporary deployed process. Viewing this as a significant technology challenge ONR approved the proposal and the project began in 1991.

"Time" was not the only challenge. It was realized that the resulting technology had to fit smoothly into the existing computing environment on ships and submarines without stressing the existing crew structure. The term "transition friendly" was often used to describe this aspect of new technology.

Between this beginning and the resultant planner, referred to as "Quick Strike Tomahawk" (QST), a computing technique was developed that far exceeded our initial expectations. In a QST prototype, executing on a Tomahawk weapon control system computer, a fully automatic GPS mission was created in less than 30 seconds. Furthermore, the system was capable of updating threats and no-fly zones within seconds. It should be noted here that while the route planning algorithm was developed under ONR sponsorship, the integration with the Tomahawk weapon control system computing architecture (which was a convincing way to exhibit the new planner) was made possible by an internal Dahlgren Division independent research grant.

The accompanying figure illustrates the planning screen for QST. Note that the missile altitude is plotted with the digital terrain elevation data, DTED, across the bottom of the figure to show that the missile never intersected, or more accurately clobbered, the ground. Operator training requirements were minimal. QST demonstrated the potential for the first time to provide Tomahawk mission planning aboard the launch platform.

Fortuitously, N86 and N87 issued a joint memorandum on Valentines Day, 1997 stating a requirement for rapid Tomahawk planning on a surface combatant. This led ultimately to the new Tactical Tomahawk cruise missile development program, for which shipboard planning was a stated requirement. The QST prototype was demonstrated to the bidding contractors and Lockheed-Martin selected QST as their approach to meeting the at-sea planning requirement. In May 1999, this contract was awarded to Lockheed-Martin, and thus QST, the ONR-funded rapid planning algorithm, was on the road to the fleet. The rapid planning capability in the Tactical Tomahawk Weapons Control System is expected to be deployed in 2004.

This successful technology development was a key enabler for the new Tactical Tomahawk cruise missile weapon system.

(Dahlgren scientists on this project were Warrington Tripp, Dr. Charles F. Fennemore, Mark Bailey, Deann Fischer and Michael Pantazopoulos. Dr. Bruce Copeland was the project leader.)



Shock Mitigation for NSW Boat Occupants

Special Forces units proved their value in Operation Desert Storm and, more recently, Operation Enduring Freedom. The Coastal Systems Station has a focused effort to ease the rigors of special operations units while on the special watercraft used for transporting forces to and from their operational areas.

Passengers and crew of U. S. Naval Special Warfare high speed planing boats experience discomfort, fatigue, and acute and long-term injuries resulting from long-term exposure to severe boat-wave impacts during extended training operations in heavy seas. Common injuries include musculoskeletal damage to the knees, lumbar and cervical spine, and the shoulders. Under Office of Naval Research and U. S. Special Operations Command sponsorship, the Coastal Systems Station is developing technology and concepts, and transitioning systems, for mitigating shock impact loads to the NSW boat occupants.

CSS has examined a number of approaches to reducing injuries for several NSW craft, but the current focus is to develop and transition advanced suspension seats for the MK V Special Operations Craft (SOC). The principal is the same as that of automobile suspension systems and common office chairs – a coil-over-shock isolator between the seat and the boat deck. However, these isolators are far from an ordinary shock. CSS engineers and the isolator development company, Taylor Devices, Inc., are including advanced internal components that automatically sense the environment and adjust its damping and stiffening properties to provide comfort to the operators in moderate sea conditions, and protection to their spine in rough conditions.

The approach taken by CSS to optimize advanced suspension systems is to measure the dynamics of the boat, advanced isolators, and occupants, and then to evaluate the injury-reduction performance with the best available seated-injury prediction model. To obtain these critical measurements with minimal interference to the NSW boat training operations, CSS developed a compact, wireless, eight-channel dynamics datalogger. A number of dataloggers are attached to the boat and seat, and worn by the seat occupants. CSS also developed a rugged IR video system to visually record the seat occupants and their audio communications, with the dynamics data and video precisely synchronized with time obtained from a GPS receiver. The time-synchronized dynamics, video, and audio data are recorded on high-capacity flash memory and standard 8-mm videotape.

CSS and its sponsors expect to transition the first suspended seat system to the MK V SOC within a few months.

(CSS engineers on this project include Jeff Blankenship, Brian Price, Pedro Bracho, Eric Tuovila, Ann Naylor, and Lang Nguyen, with Principal Investigator Ron Peterson.)



The Application and Exploitation of Mischmetal as an Incendiary Material for the 40mm Projectile used in the AC-130 Gunship.

In the spring of 1970 the AC-130 Gunship Program Officer for the Air Force asked the Naval Weapons Laboratory, Dahlgren (now known as NSWCDD) to investigate improvements to the 40mm projectile for use against trucks on the Ho Chi Min trail that fall and winter.

A value engineering team was established and through a brainstorming session developed some 54 suggestions for improvements. Two of them, the use of a pyrophoric material and a liner, were combined to produce a mischmetal liner that would fit into existing 40mm projectiles before they were loaded with explosive. Mischmetal is a mixture of the rare earth elements cerium, praseodymium, neodymium, and lanthanum, most easily described as the material used for lighter flints. There are several readily available alloys of mischmetal, but the most prevalent are those containing magnesium. Although mischmetal had many other uses - e.g. as an alloying agent to strengthen magnesium, as a scavenger for steels, as lighter flints, and even as tracer nose cones in projectiles during World War I - very little was known at the time about techniques for producing structural components from this alloy. Machining liners from cast billets was tried, but this was slow and expensive and the quality left much to be desired due to inclusions in the billets. The first suitable liners were produced with investment casting and the first 14,000 liners were produced this way. The liners were inserted into existing projectile bodies before the explosive was loaded.

The improved 40mm projectiles were tested by static detonation in a fragmentation arena along with standard incendiary rounds and the results were consistent. The improved rounds produced fires in petroleum 55-gallon drums and truck fuel tanks up to 15 feet away, while the standard incendiary round produced no fires under exactly the same test conditions.

The Dahlgren team submitted a proposal to further investigate and test this phenomenon. The effort would incorporate the mischmetal liner in a projectile design, perform a complete WR-50 safety test program, provide 300 rounds for flight-testing, and deliver 10,000 rounds for combat evaluation. The proposal was funded.

Accuracy tests were performed by firing 75 standard rounds and 75 improved rounds at plywood targets 500, & 1400 yards away as well as 10,000 yards down river. It turned out that the improved round was more accurate than the standard. Well-instrumented accuracy tests later verified the improved accuracy. An added beneficial side effect obtained by this improvement was a vastly improved night marking capability.

The first 1000 rounds were delivered from the Naval Ammunition Depot, McAlester, Oklahoma, on December 7, 1970 and the remaining 9000 were delivered in late January - six months after the first test. Two months later, full production began - about nine months after the Air Force first requested help.

Combat evaluations of the first 1000 projectiles produced a remarkable response. Later evaluations of the following 9000 projectiles rated the effectiveness at varying degrees, from two to seven times more effective than the standard incendiary round against trucks. (Thanks to Mr. Raymond Polcha for providing this story)



Side Scan Sonar Post-Mission Analysis System (PMA2000) Transitions to the Fleet

In Littoral waters mines pose a very significant threat to Navy ships and special forces units. A team led by Dahlgren Division's Coastal Systems Station (CSS) Panama City, FL is working to transition side-scan sonar post-mission analysis software, called PMA2000, to the fleet in FY03 to significantly improve their mine detection capability. At the heart of the PMA2000 software suite is a computer-aided detection and classification (CAD/CAC) method developed by the CSS team (see footnote). PMA2000 processes high-resolution side-scan or synthetic-aperture sonar imagery and is the result of a sustained research and technology development effort funded by the Office of Naval Research. Key objectives of this research are: (1) dramatically reduce false alarm rate; (2) increase probability of detection and classification against the small stealthy bottom mine (especially in the difficult littoral environment); (3) dramatically speed up post mission data analysis; (4) support the autonomous minehunting systems being introduced into the Fleet; and (5) reduce operator workload.

Computer-aided detection and classification of sea mines has been the subject of much research. Initial CAD/CAC algorithms developed in the early 1990's were proficient at detecting targets in side-scan imagery but suffered from many unwanted false alarms. If the output scores of multiple CAD/CAC algorithms were appropriately combined, then the number of false alarms would reduce dramatically while, at the same time, the number of mines detected would remain high.

First, it was noticed that, as the probability of mine detection and classification (PdPc) is pushed higher, increasingly poor mine signatures must be accepted. This is accompanied with an increase in false calls because additional clutter is detected that has signatures similar to the poor mine signatures. Secondly, it was noticed that single CAD/CAC algorithms are often plagued by many absurd false alarms that are unique to the algorithm and cannot be eliminated without negatively impacting the algorithm's mine-detection probability. "Algorithm Fusion" efficiently eliminates these types of false alarms principally because non-mine objects (especially absurd false targets) are unlikely to fool the majority of technically diverse CAD/CAC algorithms, while the actual mines are likely to be detected by the majority.

This concept of "Algorithm Fusion" is analogous to getting a second or third opinion concerning a medical diagnosis, whereby each opinion in agreement strengthens a patient's belief in the original diagnosis.

Real-time CAD/CAC was demonstrated successfully aboard a REMUS (Remote Environmental Monitoring Units) Autonomous Underwater Vehicle (AUV) during "AUVfest" in October 2001 and Fleet Battle Experiment-Juliet (FBE-J) in July 2002. The REMUS AUV was developed by Wood's Hole Oceanographic Institute and is equipped with a Marine Sonics side-scan sonar. Real-time CAD/CAC was also successfully linked with an acoustic modem at FBE-J on the REMUS vehicle, providing a near real-time underwater battle picture to the MCM Commander.

Post-mission CAD/CAC was successfully demonstrated with the Battlespace Preparation Autonomous Underwater Vehicle (BPAUV) during FBE-J in July 2002. The BPAUV was developed by Bluefin Robotics and is equipped with a Klein 5500 side-scan sonar. The BPAUV is scheduled to be outfitted with a version of real-time CAD/CAC in FY03 as well. Helicopter-towed side-scan sonar systems, such as the AQS-14 and AQS-20, are also slated to receive PMA2000 software as scheduled product improvements. Other possible transitions include the Remote Minehunting System (RMS) and the Long-term Mine Reconnaissance System (LMRS).

(POC: Dr. Gerald J. Dobeck, NSW/C CSS Code R24,

EVOLUTION OF STANDARD MISSILE WARHEADS



In 1954, an advanced series of surface-to-air missiles entered the fleet in the form of TARTAR, TERRIER, AND TALOS, the Three Ts. By the 1960's, these missiles had given way to one missile, known as the STANDARD missile. The workhorse STANDARD missile has undergone continual improvements to this day to match evolving threats. This highly capable missile has also carried a series of state-of-the-art anti-air warheads. NSWCDD has been in the forefront of warhead and lethality improvements for this missile.

In the 1960s and early 70s, the threat was big and slow aircraft such as the Soviet Bear bomber. These targets were not so vulnerable to blast so the concept of the continuous rod warhead, the Mk 51, was developed by the Applied Physics Laboratory with later technical assistance by NSWCDD. The idea of this concept was to provide a continuously expanding hoop of steel to achieve a cutting action within the physically large targets, cutting major elements of the fuselage, wings, or linear control surfaces to destroy the targets. The technical challenges of this warhead were to control the explosive interaction with the rods, to optimize the structural properties of the rod material, and to refine methods of connecting and packaging rods within the warhead explosive launch. This warhead was in the fleet until the 1980s.

MK 115 Warhead

However, in the 1970s, the threat changed to higher speed attack aircraft and anti-ship missiles that were hardened and less vulnerable to continuous rods. The Navy turned to NSWCDD to solve this problem. Vulnerability studies and operational needs indicated that penetrating fragments were needed to destroy these targets. NSWCDD engineers developed a novel broaching technique to score the warhead case in patterns to create large numbers of uniquely sized fragments. Concurrent with the warhead design was a very significant development of target vulnerability and effectiveness methodology by NSWCDD that has formed the basis of a national capability still in use. This warhead was the Mk 115 warhead, which was in the fleet from 1984 to the late 1990s. The broaching technique and equipment is still in use today for the Navy/Air Force AMRAAM missile warhead.

“Mk 125 warhead arena test at NSWCDD” MK 125 Mod 1

Again the evolving threat of the late 1980s and 1990s demanded warhead changes to retain missile effectiveness against hardened, short, fast missiles including a high diving scenario and a countermeasure threat. NSWCDD utilized technology base studies it conducted in the early 1970s-80s in aimable warheads, a NSWC-White Oak developed explosive, and a NAWC-China Lake developed missile fuze improvement to develop the world's first aimable ordnance system, the Mk 132/133 warhead section, including the NSWCDD developed Mk 125 warhead. Numerous technologies were incorporated into this warhead, including an advanced explosive, novel initiation (trigger) system, plastic and composite components, into a fully insensitive munitions compatible warhead design. This very capable warhead is expected to be in fleet use in the STANDARD Missile for many years.

The story is not over. NSWCDD is just now completing an Advanced Technology Demonstration project for a revolutionary kill mechanism. This concept replaces the traditional inert steel fragments with reactive fragments that will achieve enhanced target kill through the release of both kinetic energy and chemical energy. This approach has the potential to keep STANDARD Missile lethal for years to come.
(Walter Hoyer, G207, contributed this account)



MISSILE SYSTEMS DIVISION (G20) MISSILE WARHEAD RELATED FLEET TRANSITIONS		
<u>Where it went</u>	<u>What it was</u>	<u>When it happened</u>
PENQUIN Bullpup	A penetrating warhead	1956-60
TOMAHAWK Bullpup B	penetrating warhead	1959-62
PHOENIX Mk 82 WDU-29B	continuous rod warhead fragmenting warhead	1962-71 1980s
SPARROW Mk 38 Mod 0 WAU-17B	continuous rod (White Oak) fragmenting warhead	1959-62 1980s
TERRIER Mk 3	fragmenting warhead	1950s
TARTAR/TERRIER Mk 10	continuous rod warhead	1950s
STANDARD MISSILE Mk 90 Mk 115	fragmenting warhead fragmenting warhead	1960s 1980s
Mk 115 Mod 1	fragmenting Warhead	1980s
Mk 125 Mod 0	warhead of Mk 113 ord sys	1987-92
Mk 125 Mod 1	warhead of Mk 133 ord sys	1990s
EVOLVED SEASPARROW Mk 139	warhead	1990s
ZUNI ROCKET Mk 32	warhead	1960s



Early Dahlgren Roles in the Development of the Submarine Launched Ballistic Missile Guidance System Poseidon Ballistic Missile

For more than forty years the Dahlgren Division of the Naval Surface Warfare Center has developed the computer programs used to target, prepare, and launch the Navy's submarine launched ballistic missiles. The story of two specific contributions – the development of the POLARIS presetting process and the solution of the Multiple Independently Targeted Re-entry Vehicle (MIRV) guidance problem for POSEIDON – are provided here by Mr. Robert V. Gates.

The role of the Naval Proving Ground (as the Lab at Dahlgren was known from 1939 to 1959) in ballistic missiles actually predates POLARIS. Our early efforts included performing trajectory and guidance analyses of the Jupiter missile for the Army Ballistic Missile Agency in 1954-55. This early experience and the computing power provided by the Naval Ordnance Research Calculator (NORC), the most powerful scientific computer then in operation, positioned the laboratory at Dahlgren to seek tasking from the Special Projects Office (SPO) to help develop the first submarine launched ballistic missile. Dr. Russell Lyddane and Mr. Ralph Niemann presented Dahlgren's capabilities to SPO in early 1956. When this first approach was unsuccessful, Dahlgren, building on a small reentry study performed for the SPO Missile Branch and independent study of the proposed POLARIS guidance method by Dr. Charles J. Cohen, was accepted in a self-initiated technical advisory role.

In 1958, Dahlgren was given the opportunity that led to the role that it has filled for every SLBM system since – developing fire control and targeting products – when SPO asked it to study methods for computing missile-aiming data on board the submarine. When a missile is to be launched to a given target, guidance data (calculated from the location of the launch and intended impact points and desired missile trajectory characteristics) must be loaded into the missile.

If the missile is to be launched from a moving platform, the guidance data will ideally be computed immediately before launch using real-time submarine navigation system inputs. In the late 1950s, computer technology did not support this approach. Digital computers were too large for shipboard installation and too unreliable to be placed in the critical path for launching a weapon. Dahlgren developed a process that included computing trajectory simulations on the NORC in order to develop numerical functions of the guidance data in terms of launch and target point coordinates. These functions were used at Dahlgren to generate the data transferred to the submarine on target cards. When the USS *George Washington* (SSBN 598) departed Charleston, S.C. on 15 November 1960 on the first nuclear deterrent patrol, it carried some 300,000 target cards prepared by the team at Dahlgren.

As early as 1962, SSP began considering a follow-on to the POLARIS A3. A favored concept was to carry multiple re-entry vehicles on the missile, a concept that became the POSEIDON missile. Carrying multiple independently targeted re-entry vehicles (MIRV) on a single missile presented significant problems with missile guidance.

The POLARIS guidance algorithm ("Q guidance") was a form of implicit guidance, i.e. the in-flight calculations did not require knowledge of missile position and velocity or an in-flight gravity model. It was quickly decided that this guidance approach was not adequate for POSEIDON since both missile accuracy and preflight computational load on the submarine fire control system were unacceptable. Dahlgren embarked on a study of the problem in December 1964 and developed a trajectory model that incorporated explicit guidance (i.e., that includes an in-flight gravity model, computes missile position, and derives guidance commands that steer the missile to the desired position and velocity for re-entry vehicle deployment). This simulation was used to study accuracy and achievability over a range of trajectory conditions.

Dahlgren developed a missile guidance algorithm that used a correlated velocity computation developed by Dr. Russell H. Lyddane, and Keplerian equations with an inverse square (round earth) gravity model. The key to this was the fire control computation of offsets to the target point that compensated for the simplifications in the in-flight guidance algorithm for gravity and earth's atmosphere during re-entry. This approach used the capabilities of both fire control and in-flight guidance to solve the problem. Dahlgren's approach and analysis was presented to an SSP conference in early 1965. By the summer of 1965, Dahlgren was notified that its approach was to be the baseline for developmental and operational implementation.

In less than ten years Dahlgren had progressed from a self-initiated technical advisory role to become a key member of the SLBM fire control/guidance team. The concepts developed for POSEIDON have continued in principle through TRIDENTs I and II. Improvements in algorithms, better data, and more computing power in fire control have allowed the full potential of the concept to emerge.



Standard Missile Pitchover Stability

Dual Salvo SM-2 Block IIIB Firing aboard *USS Decatur*

The Dahlgren Division of the Naval Warfare Center has made many valuable contributions to STANDARD Missile failure analysis. One of the most notable was the analysis that succeeded in identifying and solving a long-standing and extremely challenging stability problem with SM-2 Block IIIB. Although STANDARD Missile has experienced several major evolutionary design changes over its 30-year life span perhaps the most important of these has been the transition from rail to vertical launch. Thus, in order to engage short-range targets, the missile must now execute a high-g pitchover maneuver. This has placed severe demands on the missile autopilot that has remained basically unchanged from the early roll dithering design.

Pitchover stability has always been an issue with the vertical launch missile. However, prior to the IIIB tests, the missiles had always recovered completely. The IIIB is the latest version of STANDARD missile to enter the fleet and is equipped with a side mounted infrared seeker to aid in terminal homing. During short-range development tests of the IIIB missile each of the three missiles launched experienced complete catastrophic flight failure. A decision to proceed to production of the missile was put on hold pending resolution of the stability problem. The IIIB instability was characterized by a rapid divergence of the tails to the mechanical limit of 55°, roll dither breakup, and violent out-of-plane yaw.

By means of theoretical stability analysis and computer simulation NSWCDD was able to identify the cause of the problem. The sequence of events leading to the failure was as follows: At about 1.2 degree angle-of-attack, as the missile pitches nose down, with roll angle 45°, the center of pressure of the aerodynamic force moves suddenly forward resulting in a strong reversal in the sense of the static pitch moment from statically stable to statically unstable. This caused the missile to overshoot the desired trim angle of attack into a region of higher incidence where wind tunnel tests had previously revealed the existence of a strong negative roll moment in the 45° roll orientation. Without the seeker this is a perfectly symmetric roll orientation in which no such roll moment exists. In attempting to maintain the 45° orientation the IIIB roll autopilot applied positive roll tails. Due to strong high angle of attack aerodynamic control cross coupling the roll tails produce a yaw moment that is countered by the yaw autopilot. In turn the yaw tails further increase the original negative roll moment and the unstable sequence is repeated.

Once the problem was understood a solution could be attempted.

The high angle of attack aerodynamic characteristics of STANDARD missile are extremely dependent on aerodynamic roll angle. The IIIB instability occurred while the missile attempted to sustain a 15-g pitchover in the cross or 45° roll plane. In this configuration both the pitch and roll moments are inherently destabilizing. On the other hand in the plus or zero roll configuration the out-of-plane side moment is de-stabilizing. Maximum pitchover stability was shown to result from maneuvers in asymmetric roll planes close to 22.5°. The proposed solution was then to perform the pitchover maneuver with a constant roll command of 22.5° in conjunction with stiffening the roll autopilot control loop.

The solution was validated during live-fire exercises aboard the *USS Decatur* at the Pacific Missile Range Facility in December 1998. Eight first production SM-2 Block IIIB tests validated the missile's effectiveness against a variety of real world threats. The unparalleled success of this test ensured the continued full rate production of the SM-2 Block IIIB missile. Because of the efforts of NSWCDD, the Navy can send ships to sea confident that they will carry reliable ordnance to defend the fleet.



Draper Laboratory Incorporates NSWCDD Guidance Algorithm in Low Cost Guidance Electronic Unit Flight Software

Under the Low Cost Guidance Electronic Unit program (LCGEU), Draper Laboratory is developing an alternative guidance electronic unit for the EX-171 Extended Range Guided Munition (ERGM) with the goal of reduced cost. The performance of the unit will be demonstrated through a series of flight tests. In 2001 Draper successfully incorporated a composite navigation system (CNS) guidance algorithm, developed at Dahlgren, into the operational flight software of the LCGEU.

Appendix C

The guidance algorithm maximizes the range and cross-range capability and allows time-of-flight control while flying the projectile to the desired terminal velocity orientation. The algorithm maximizes range by means of energy management in the vertical plane and can command optimal cross-range turns to maximize the retargeting footprint of the projectile. The guidance algorithm provides a compact closed-loop formulation while matching the performance of optimized open-loop trajectories.

The algorithm controls the time-of-flight to allow a salvo of projectiles to arrive simultaneously. This Multiple Simultaneous Round (MSR) requirement maximizes the lethality of the salvo. The time of flight control achieves its objective by trajectory shaping and corrects for pre-launch and unknown variations that are observed in-flight. The variations known before launch such as the planned salvo-firing rate are compensated for in the fire control trajectory parameter selection. The in-flight observed variations include winds, muzzle velocity variations, and drag variations and require an active in-flight algorithm for their correction. Range maximization and time-of-flight control are in conflict and as such the span of target ranges at which the MSR requirement may be achieved is restricted to a subset of the feasible span of ranges. Beyond this maximum range the guidance must provide pure energy management in order to maximize the range extension subject to the miss distance and the final velocity orientation requirements.

During the ascent, the round is unguided until the flight path angle is less than the guidance start angle (θ). At this point, the guidance algorithm is initiated. The guidance shapes the trajectory in a vertical plane defined by the x-z axes of the Earth local tangent frame at the missile position with its x-axis aligned with the missile's current bearing. The z-axis of this local tangent frame points along the local gravity vector. The vertical plane trajectory shaping serves to minimize drag losses and control time-of-flight. The homing commands normal in the local tangent frame are unrestricted throughout the guided phase.

The composite navigation system guidance consists of three terms. The first is the explicit guidance algorithm that ensures that the missile flies to the target and arrives with a selected velocity orientation. The second term is a bias for cancellation of the gravity acceleration and for in-flight time-of-flight control. The function of the third term is to fly the projectile along an optimal flight path to conserve energy. The guidance algorithm creates a composite commanded acceleration based on a range-to-go weighted sum of the individual components.

The composite navigation system (CNS) guidance algorithm was developed in 1999 by Craig Phillips and Steve Malyevac of the Missile Systems Engineering Branch (G23) under the Office of Naval Research Air and Surface Weapon Technology Program. The algorithm was transferred to Draper Laboratory in the Spring of 2001. Mr. H. C. Wendt of the Fuze Branch (G34) facilitated the transition of this technology through his role as NSWCDD project manager for the LCGEU.

Tactical Tomahawk Guidance Algorithm



One of the requirements for the Block IV Tomahawk cruise missile, also known as Tactical Tomahawk, is the ability to strike targets whose precise location is not known at the time of mission planning. Because the Tactical Tomahawk will have a satellite data link, it will be possible to redirect the missile to a new target location while the missile is in flight. One method of redirecting the missile to a new target location, called an aimpoint update, uses a message with only the target location and an altitude for the missile to fly. With an aimpoint update, the guidance logic embedded in the missile controls the route trajectory rather than being supplied by mission planning. The original guidance design logic was to simply have the missile make a single turn toward the new target bearing then fly a great circle trajectory to the target.

At this same time, in 1999, work was proceeding on the Quick Strike Tomahawk planner at Dahlgren (see the Leading Edge Vol. II issue no.4, page 5). The aimpoint update was being used to guide simulations of loitering Tomahawk missiles to an emergent target. It was demonstrated during this effort how the original aimpoint update guidance logic would not allow the missile to successfully fly to a target if the target were relatively close to the missile. The problem was similar to the problem of trying to run over an object with a car when the object is a few feet to the left of the driver's door. Making a sharp turn to the left will not work because the car's turn radius is much larger than the distance to the object. The car would make a complete circle, come back to its starting point, and never be on a path to hit the object.

An algorithm was developed that would appropriately guide the missile to reach any target regardless of its distance and orientation from the missile. An initial turn away from the target is used in situations where the missile is too close to perform a single turn maneuver. The turn away from the target is calculated by the missile in such a way as to minimize the overall flight path distance to the target. The algorithm was converted to aimpoint update steering logic and was tested at Dahlgren. After sufficient testing, the new guidance logic was proposed to Raytheon, the prime contractor for the Tactical Tomahawk. The logic was tested by Raytheon who agreed that the new guidance would solve the problem of requiring mission route planning to reach these targets. Since the missile was still in the design phase at this point, the new logic was included in the initial missile baseline.

By implementing the more robust aimpoint update guidance logic in the missile, the entire retargeting process is simplified such that an appropriate route to the new target can be generated by the in-flight missile regardless of where it is relative to the target.



Computational Fluid Dynamics for Missile Vertical Launching Systems

Appendix C

of the most important components of vertical launching systems (VLS) for ship-launched missiles is the gas management system. The purpose of the gas management is to vent the rocket motor exhaust products safely to the atmosphere, without causing damage to the launcher, the missile, or the ship. These exhaust products can reach temperatures as high as 6500 deg F, and achieve velocities over three times the speed of sound. The direct impingement of these products can burn through a two inch steel plate in a few seconds. In order to design and maintain VLS gas management systems, both efficiently and with the lowest possible cost, it is highly desirable to understand the complex fluid dynamics that takes place inside the system.

Approximately 10 years ago, an effort was started to improve and develop computational fluid dynamics methods for calculating flows in VLS gas management systems. The Surface Weapons Technology Program in ONR and the VLS Program Office in NAVSEA supported this task. Support of the programs was crucial to the success of this effort. The technical requirements for this effort were set high. We wanted a computer code that could solve any complex flow environment that we were likely to encounter. Thus the code had to be able to solve flows that were transient (moving shock waves), compressible, turbulent, two-phase (liquid aluminum oxide particles and gas), and multi-component, (exhaust products and air). In addition, we wanted the code to have a moving grid capability in order to calculate the exhaust plume flow behind the missile as it traveled up the missile canister and left the ship. It should also have the capability to calculate the effects of the rocket motor plume on the deck of the ship as the missile exited the launcher. At that time, there were no codes in existence that could meet all of these requirements. Our basic approach was to find the code that was most able to meet these requirements, and then to add additional capabilities as they were developed. After an initial evaluation period, we found that the Navier-Stoke code CRAFT being developed by a company called CRAFTech came closer to meeting our requirements than any other.

Over the years we have worked very closely with CRAFTech to develop a code that meets all of the above requirements. The code has been used for many different investigations. These investigations have included the effects of restraining missiles during an inadvertent ignition of the rocket motor, and the effects of the launcher exhaust plume on the missile as it leaves the launcher. Calculations have been performed for the Mk 41 VLS launcher, the Concentric Canister Launcher and Lockheed-Martin's VLS 2100 launcher.

During 1998 the code was used to investigate the causes of an actual restrained missile firing due to the inadvertent ignition of a TOMAHAWK cruise missile on board the USS Coral Sea. The restrained firing caused a burn-through in the bottom of the canister wall. Figure (1) shows some of the calculated results from that investigation. The figure shows the computational grid used in the investigation and Mach number contours of the flow as it exits the rocket motor into the bottom of the canister. It was shown that the probable cause of the burn-through was wall jets related to the interaction of the exhaust plume with extended thrust tabs near the rocket motor exit. Figure (2) shows the velocity vectors of the wall jets as they flow across the VLS base-plate toward the portion of the canister wall where the burn-through occurred.

More recently, the code has been used to evaluate flow calculations performed by United Defense for a single-cell launcher concept. Currently the code is being used to predict the effects of the rocket motor plume on the deck of a ship resulting from a candidate missile being considered for ballistic missile defense.



The Fast Analysis Strike Tool – Collateral Damage

The idea of limiting the collateral or unintended effects of a military attack on a civilian population and civilian infrastructure is not new. In an era of almost instantaneous communications, the collateral damage from an attack is no longer just a regrettable consequence of war; it is a serious threat to the credibility of the United States as a promoter of human rights and humanitarian causes. The advent of precision guided weapons, showcased in the Gulf War and subsequent attacks, and the necessity of attacking targets close to urban centers, turned collateral damage into a major consideration for military planners.

A four tier system was adopted by the Targeting Community to describe levels of analysis of increasing complexity related to estimating pre-strike collateral damage. If a clear strike can not be identified during Tier I analysis, then Tier II analysis is required, and so on up through Tier IV analysis. Tier I, Tier II and Tier III analysis are done in the field. Tier IV analysis is done by the Joint Staff. Tier IV analysis is much more complex and time consuming, resulting in the development of a detailed urban scene and physics based analysis. Previously Tier II and Tier III analysis were manual, time consuming and overly restrictive in order to err on the side of safety. The Fast Analysis Strike Tool – Collateral Damage (FAST-CD) was developed by NSWCDD under guidance of the joint staff to automate Tier II and Tier III analysis.

The major damage mechanisms for conventional military weapons are airblast and fragmentation. Airblast effects on people include temporary tonal shift (TTS or ringing of the ears), eardrum rupture, and lung damage due to direct effects of exposure to an explosive shock wave. The lowest level of permanent damage to people is taken to be eardrum rupture. Fragmentation can cause injury or death to people. These two criteria are used to determine the range of unacceptable collateral damage for people in collateral damage analyses.

FAST-CD was originally named Bugsplat because the shape of fragmentation patterns projected onto a two-dimensional plane resembles the shape of a bug splatting onto the windshield of a car. It operates by having a library of pre-computed results of blast and fragmentation for common weapons. The results are turned into a picture and overlaid on a reference picture. The images are then scaled to match dimensions. In addition, damage contour rings can be displayed to show the stand-off distance for several different blast and fragmentation effects. The operator can move and rotate the image and contours to quickly determine whether a Tier IV analysis is required.

Figure 1 shows a sample output from the FAST-CD tool. Four weapon “bugsplats” along with the damage contour rings are shown on the image.

FAST-CD has been deployed to several military sites including land-based and ship board installations. It was heavily used during the recent war in Iraq. The Targeting Community was able to successfully target using FAST-CD minimizing the number of Tier IV assessments required which resulted in better support to troops in the field and a shortened air-tasking-order (ATO) cycle. The need to predict the damage from blast weapons transcends the Navy. All branches of the armed forces need ways to determine how much collateral damage strikes will do. They also need ways to determine their own vulnerabilities to terrorist attacks. The Targeting and Vulnerability Analysis Branch of the NSWCDD continues to develop the tools and techniques to help satisfy these requirements. The future of this technology lies in the continued improvement of computers. As they become more powerful, higher fidelity models will be incorporated into the tools to produce better approximations of terrain features, etc.

VLSTRACK CBW HAZARD ASSESSMENT MODEL



Vapor, Liquid, and Solid **TRACKing** (VLSTRACK) chemical and biological warfare hazard assessment model was developed by what is now the Chemical, Biological, and Radiological (CBR) Battle Management Branch (B55) during Operations Desert Shield/Desert Storm (1990) to meet an immediate operational need for a shipboard chemical warfare hazard assessment model. VLSTRACK was fielded to ships and shore facilities in the Persian Gulf region in Nov 90, and its associated biological warfare hazard assessment modeling capability was used at Dahlgren Division and what is now the Defense Threat Reduction Agency (DTRA) to support military operations from the continental United States. The model was subsequently fielded to the US Navy fleet both as a stand-alone application and as part of the Naval Integrated Tactical Environmental Subsystem II, a meteorology and oceanography database and tactical decision aid software system developed by the Space and Naval Warfare Systems Command (SPAWAR).

Since 1990 VLSTRACK has evolved through release of successive model versions to meet the increasing needs of users and to take advantage of advances in software technology. Key components of the model today involve characterization of the chemical or biological agent release, retrieval of meteorology-forecast data, atmospheric dispersion, agent fate on surfaces, and interpretation in terms of human toxicity. An example hazard prediction is provided in Figure 1. The developer team has been recognized for fielding this important analysis tool: in Nov 96 VLSTRACK was declared to be the DoD standard model for estimating hazards resulting from intentional release of chemical or biological warfare agents, a role it continues to this day.

VLSTRACK has been used at the Dahlgren Division over the years to support acquisition programs for biological warfare agent point detection, chemical warfare agent point and stand-off detection, and theater ballistic missile defense. Dahlgren Division has used VLSTRACK for simulation and analysis of incidents thought related to Gulf War Illness and what-if scenarios in support of current military operations. The other Services, intelligence agencies, federally funded research and development centers, national laboratories, and military agencies of key allies use VLSTRACK for similar applications. VLSTRACK was included in recent demonstrations of how Dahlgren Division products and capabilities can operate and exchange information within both an ArcView geographic information system and the current operational command and control system for applications such as base and infrastructure protection.

The latest version of VLSTRACK has been transitioned to SPAWAR for implementation under the next generation of the Global Command and Control System-Maritime (GCCS-M) and as part of the Joint Effects Model (JEM). JEM is a current acquisition program creating a chemical, biological, radiological, and nuclear (CBRN) hazard assessment model starting with the best capabilities from existing models. JEM will be used with the Joint Warning and Reporting Network (JWARN) for operational CBRN incident warning, reporting, hazard assessment, and monitoring and with the Joint Operational Effects Federation (JOEF) for planning, training, and exercises involving CBRN releases. Upon successful development and testing, JEM will become the official DoD standard model for estimating hazards from CBRN incidents, and VLSTRACK's job will be done.

Author and Point of Contact: Mr. Timothy J. Bauer, B55



Appendix D

Appendix D: Examples of disruption in the scientific workforce leading to failure.

**Appendix D**

Welcome to the Dark Ages!
AD 450 to 1000.

The beauty of the Greek and Roman Empires is long gone! The ruling system has collapsed and taken with it stable government, schools, libraries, a uniform currency, and a common language. Barter now replaces money as the major purchasing system. Cities and towns have been destroyed and transportation between them is extremely difficult, if not impossible.

This era is not without government though. The Roman Catholic Church remains a strong unifying force. In addition, medieval civilization clings to a very simple form of government called "feudalism".

<http://library.thinkquest.org/2834/gather/darkage/darkage.htm>

**Appendix D****Exodus of scientists from Russia after 1917**

“It is perhaps only now that it is possible to even begin measuring how devastating the effects of the protracted decades of Soviet rule were — whether the terror under Stalin or the ossification under the aging Brezhnev and his immediate successors.

No European country — and very few countries anywhere — have experienced anything comparable. Especially crippling for the country was the hemorrhaging brain drain driven by the massive exodus that followed the October Revolution.

In the 20 years after 1917 — in other words, before the institutionalised Stalinist terror — over three million people left the country, many of them scientists, writers and artists. “

<http://www.theglobalist.com/DBWeb/StoryId.aspx?StoryId=3568>



Appendix D

The exodus of scientists from Germany in the 1930s

Hitler to Planck: mid 1930s

- “Our national policies will not be revoked or modified, even for scientists. If the dismissal of Jewish scientists means the annihilation of contemporary German science, then we shall do without science for a few years” (Jungt, 43).

1933: Einstein moves, Berlin to Princeton.

- French physicist, Paul Langevin, “It’s as important an event as would be the transfer of the Vatican from Rome to the New World. The Pope of Physics has moved and the United States will now become the center of the natural sciences.”

<http://www.siu.edu/~jpogats/IS364/PDF/Exodus.pdf>



Appendix D

Space Shuttle program

As the Columbia Accident Investigation Board writes its report on the shuttle disaster, it will have to explore the critical breakdown in communication that left the leader of the mission management team without any knowledge of three requests for spy satellite images of the damaged shuttle.

A flurry of e-mail messages disclosed under the Freedom of Information Act showed that several NASA engineers around the country wanted the images. One made an informal request that NASA officially withdraw, and a top official at the agency's headquarters actually turned down an offer of help from an Air Force surveillance agency.

The information now in the public record does not establish precisely why the agency did not take the issue of debris more seriously and follow through on the first impulse of some of its engineers to get pictures of the shuttle in orbit. The public will have to wait for that explanation in the release of the report by the Columbia Accident Investigation Board.

But some things stand out already.

For example, the leader of the mission management team at Johnson Space Center, Linda Ham, said she never learned of the requests for images. In fact, Ms. Ham told reporters at a briefing on July 22 that because she had heard that someone wanted to make such a request, she spent much of Jan. 22, in the middle of the mission, asking about it, but learned nothing.

She said she asked who wanted the images at the Mission Evaluation Room, where a cluster of middle managers troubleshoot engineering issues during flights. Working in that room was the chief engineer of the shuttle's structural engineering division at the Johnson Space Center, Alan R. Rocha, known as Rodney. In an interview with ABC television after the crash, Mr. Rocha said he regretted not having spoken up at the mission management team meeting, at which Ms. Ham presided.

If the accounts of both managers are accurate, Mr. Rocha not only did not volunteer his desire for the images at that meeting, but his wishes were not conveyed after Ms. Ham asked questions at the office where he worked.

"It never, never came up," Ms. Ham said.

The flow of information, or the lack of it, displays another characteristic about the National Aeronautics and Space Administration that the board may analyze: the agency's approach to peer review and accountability. Ms. Ham said in her meeting with reporters last month that she had considered whether debris shed on liftoff, now believed to be the fatal flaw, could have damaged the orbiter. But she said she had relied on an analysis by Boeing that indicated no threat to the mission from the impact of the foam.

"We must rely on our contractor work force who had the systems expertise to go off and do that analysis," she told reporters last month. "We don't have the knowledge to do that or the background or expertise to do that kind of thing."

That explanation does not satisfy one member of the shuttle team, who attended some of the meetings in question and spoke only on the condition of anonymity. "Part of the problem is that everybody assumed that someone else would do it, and the old axiom of business is no one ever wanted to be first," the engineer said.

This unwillingness to be first to discuss a problem is well known among contractors that work with NASA, says Joseph Grenny, an organizational consultant who has worked with agency contractors. The companies call that phenomenon "NASA Chicken."

Mr. Grenny, a co-author of the book "Crucial Conversation: Tools for Talking When the Stakes Are High," says people are reluctant to raise any flags that can slow a project and carry political or economic risks. Instead, they say, "I will wait, bide my time and hope others speak up first," he said.

The NASA engineer explained, "The NASA culture does not accept being wrong." Instead of a culture in which "there's no such thing as a stupid question," within the agency "the humiliation factor always runs high," he said.

On Friday, NASA officials did not respond to requests for further comment from Ms. Ham.

Testimony and documents that the agency has released do not show that anyone reviewed the Boeing analysis skeptically. Transcripts of the meeting of the mission management team in which the Boeing report was briefly discussed show a presentation that dealt lightly with the degree of uncertainty and risk in the report. Ms. Ham cut off that presentation with assertions that the analysis showed no serious risk to the shuttle or its crew.

Edward R. Tuftle, a professor emeritus at Yale University and an expert in the visual presentation of evidence, has expressed his dismay at the content of the transcripts from the Jan. 23 meeting. In March, Professor Tuftle published a blistering critique of the Boeing studies used by NASA. He has since included the material in a course he teaches on presenting data and information, and in a booklet. He calls the crucial slide about the foam strike a "PowerPoint festival of bureaucratic hyper-rationalism" because, he said, it conceals far more than it reveals.

The optimistic conclusion that the foam probably did no harm is undercut by the data in the presentation — including the fact that the piece of foam that hit the orbiter was 640 times as large as anything that NASA had tested.

Still, a careful reading of the slides would show the great uncertainty in the research, Professor Tuftle said.

"It's very clear that all they were getting were in effect the executive summaries of the Boeing reports, even a filtered executive summary," he said. "It was like a double filtering."

The summary lines on the slide were "way more sanguine about the Columbia than the actual report," he said. "The summary lines don't reflect a lot of the doubts and uncertainties and error possibilities in the report itself."

The Boeing report, if read carefully, "raises real uncertainties and poses rather threatening issues" about whether the impact was on tile or on reinforced carbon carbon, he said. Anybody looking at the figures describing the size of the foam chunk should have known the problem was beyond any test data, he added.

"In a sense, the real fault of upper management is they didn't look beneath the optimistic surface of the reports of their subordinates," he said.

Ms. Ham's assertion at the briefing for reporters that she did not have the tools to perform a more thorough analysis is absurd, Professor Tuftle said. "I'm from out of town, and I can see all the stuff on that slide."

An administrator should have seen much more, he said, and dug deeper.

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28 January 2005



Appendix D

The ERGM program.

From "Smart Shell Hits Snags" Defense News, 1 November 1999

" Raytheon is developing ERGM under a contract that originally was awarded to Dallas-based Texas Instruments in 1996. Raytheon acquired Texas Instruments in 1997." (Probably they acquired the Government or Military Operations portion of Texas Instruments, not the whole company.)

And:

"A significant portion of the program's engineers refused to transfer when Raytheon management consolidated missile and munitions programs in Tucson, Ariz facilities."

(about 1998, but it had clearly happened by November 1999. Raytheon had also acquired the Standard Missile business and the CIWS business from General Dynamics, and also consolidated it in Tucson. This is the same example that Colvard cites - the moving from the GD Pomona facility to Tucson. Raytheon also got the Tomahawk business from GD . They also moved their Hawk/Patriot/Tartar product line - at least the missile part from Tewksbury, Mass to Tucson, Ariz and lost more people in the process. Someone should write a book about post-cold war defense consolidation in the US.)

As another aside, in 1996, the ERGM IOC was FY01. In 1999, the ERGM IOC had slipped to FY04. The current projected IOC is FY11, at best.



Appendix D

Standard missile program

- The Navy lost its surface-launched missile engineering capability, at least for the short term, in a defense industry shakeout that followed the Cold War. General Dynamics Corp. operated the Navy Industrial Reserve Ordnance Plant in Pomona, Calif., for years. The organization ultimately moved to Tucson, Ariz., after being shifted from General Dynamics to General Electric to Raytheon. Many people who had worked for years building Navy missiles did not relocate. General Dynamics' move may have been a sound business decision, but the Navy was left to reconstruct a technical capability that had cost the government billions.

Colvard – “Savings can have a high price.”



The End

28 January 2005

B-124

Extra Material

12 April 2005

B-125

Ref: "The S&T Innovation Conundrum" Coffee, Dahlberg, and Zimet, June 2005 final draft.

"A special situation exists for Defense R&D, where the beneficial effects of the free market do not apply due to the small market size and the specialized nature of warfare. In this case the United States Constitution assigns implicitly governance for the full spectrum (prospecting phase and mining phase) of R&D to the federal government."

"the inadequacies of our systems of research and education pose a greater threat to U.S. national security over the next quarter century than any potential conventional war that we might imagine. American national leadership must understand these deficiencies as threats to national security. If we do not invest heavily and wisely in rebuilding these two core strengths, America will be incapable of maintaining its global position long into the 21st century." {Hart-Rudman, 2001}.

12 April 2005

Vice Admiral Paul Sullivan, COMNAVSEA, says...

“Everything we do should focus on putting capabilities in the hands of the war fighter,” said Sullivan. “All of our efforts must be aligned to deliver world-class readiness today, world-class capability tomorrow, and avoid technological surprise the day after tomorrow.”

Vice Adm. Paul Sullivan, commander of the Naval Sea Systems Command (NAVSEA) outlined his focus areas for NAVSEA and its affiliated Program Executive Offices (PEOs Ships, Carriers, Submarines, Integrated Warfare Systems and Littoral and Mine Warfare) 15 Aug. 2005.

12 April 2005

27 July 2005 - "Shuttle Discover Program Manager Bill Parsons, speaking at a post-MMT press briefing yesterday afternoon said: "We had a debris event on the PAL ramp along the LOX field line - below the point where the LH2 ramp begins. Our expectation is that we would not have an unexpected debris event. The PAL ramp is one area we should have reviewed."

12 April 2005

China News

Between 1996 and 2001, China increased its number of science and engineering PhDs almost two-fold to 8,153. Governmental spending on R&D doubled between 1997 and 2002 to roughly \$0.9 billion. Add to that the private investment in R&D, and the total Chinese R&D investment stands at 1.29 percent of GDP (current as of 2002).

The U.S. hasn't lost its position of pre-eminence yet, but there are sobering indications that it is losing ground. In 2001, 25,509 Americans earned doctoral degrees in science and engineering, down from 27,243 in 1996. U.S. government investment in R&D in math, engineering and the physical sciences stands at just 0.16 percent of GDP, down from 0.25 percent in 1970.

U.S. business interests are taking notice of this trend. The Business Roundtable, an association of chief executive officers of leading U.S. corporations with a combined workforce of more than 10 million employees, views the lack of science and engineering students in the U.S. as a threat to the country's future global competitiveness. It notes that since 1980, the number of science and engineering jobs in the U.S. has grown at five times the rate of overall employment, but that the number of college degrees awarded in those fields has not kept pace. Its study, *Understanding & Responding to Imbalances in Engineering & IT Labor Markets*, speculates that inadequate science and math education in primary and secondary schools may be one reason that fewer than six in 100 U.S. students seek science or engineering degrees [www.businessroundtable.org/pdf/20040930002Harrington.pdf].

12 April 2005

B-129

In his wartime position paper, {Deke} Parsons stated that the military services needed their own research and development laboratories. He felt it unrealistic "to expect industrial laboratories to concentrate first class talent on the solution of military problems whose solution requires years of hard work and has no obvious industrial application." At the same time, he recognized the need within these laboratories to guard against "dry rot, the curse of peacetime military research." He advocated great care in selecting officers to command military research and development establishments, emphasizing the need for youthful officers with flexibility and optimism. "In order to get these characteristics," he said, "these posts should be made stepping stones up rather than berths for those who are over the hump."

Reference: Page 208, "Target Hiroshima – Deke Parsons and the Creation of the Atomic Bomb". By Al Christman. Naval Institute press, 1998

12 April 2005

“The committee commends DOD for the response of the defense science and technology base to emerging critical operational needs in support of the global war on terrorism and Operation Iraqi Freedom, particularly countermeasures to improvised explosive devices and advances in force protection. The committee also commends the DOD for measures being taken to recruit and maintain a skilled defense science and engineering workforce, and has recommended a provision that will build on last year’s congressionally mandated SMART program (Science, Mathematics, and Research for Transformation) to provide education assistance to those seeking a baccalaureate or advanced degree in science and engineering disciplines critical to national security.

However, despite the positive aspects of the Department’s science and technology program, the committee is concerned about long-term projections for reductions in DOD science and technology as a percentage of total obligation authority. The committee cannot emphasize too strongly the need for the Department to maintain a strong and robustly funded science and technology program that will provide the advanced technologies needed to assure technical dominance of U.S. Armed Forces on any current or future battlefield.”

**HOUSE ARMED SERVICES COMMITTEE APPROVES
FISCAL YEAR 2006 DEFENSE AUTHORIZATION BILL**

19 May 2005 <http://armedservices.house.gov/>

12 April 2005

"Not everything that can be counted counts and not everything that counts can be counted." (Albert Einstein)

12 April 2005

May 2005

<http://www.nationaldefensemagazine.org/issues/2005/May/Future>

Future Pentagon Investments To Reshape Defense Industry

By Roxana Tiron

Despite being heavily committed in the Middle East, Defense Department officials argue that long-range investment decisions must begin now if the military is to have crucial capabilities 20 years down the road.

...Officials believe the paramount obstacle to developing critical defense technologies is the shortage of specialists who are educated across the sciences.

The hot areas in need of expertise—ranging from associate degrees to PhDs—are chemistry, physics, applied mathematics, biology, computer science, all facets of engineering, project and program management, cognitive and human-factors science, and language, Payton (Sue Payton, acting deputy director in Segal's office) said. "We must invest in the future and we must invest today," she urged at a conference organized by the American Institute of Astronautics and Aeronautics.

12 April 2005

9 May 2005

Wayne, I just got my hard copy of the May 9 DN. The letter is there (slightly edited, probably improved). There is also a new DN editorial, arguing, in part, that the government needs a larger, well educated, well trained acquisition corps with years/decades of experience to oversee all this complexity... Now, if enough people actually believed that, then our arguments on how, precisely, you develop and train such a corps might find some traction. Robin

From: 9 May 2005, Defense news COMMENTARY.

...

• **Fourth, government needs to expand its professional acquisition corps — the group of well-trained, well-educated people who handle the difficult, exacting job of overseeing the development and acquisition of horrendously complicated war machines. The group must be large enough to oversee scores of major projects, and be compensated well enough to keep them at it to develop years or even decades of expertise. This expertise is key. It will allow the Pentagon to keep industry from introducing ill-considered aspects to a contract, and it will keep the military from piling needless requirements onto the contractors.**

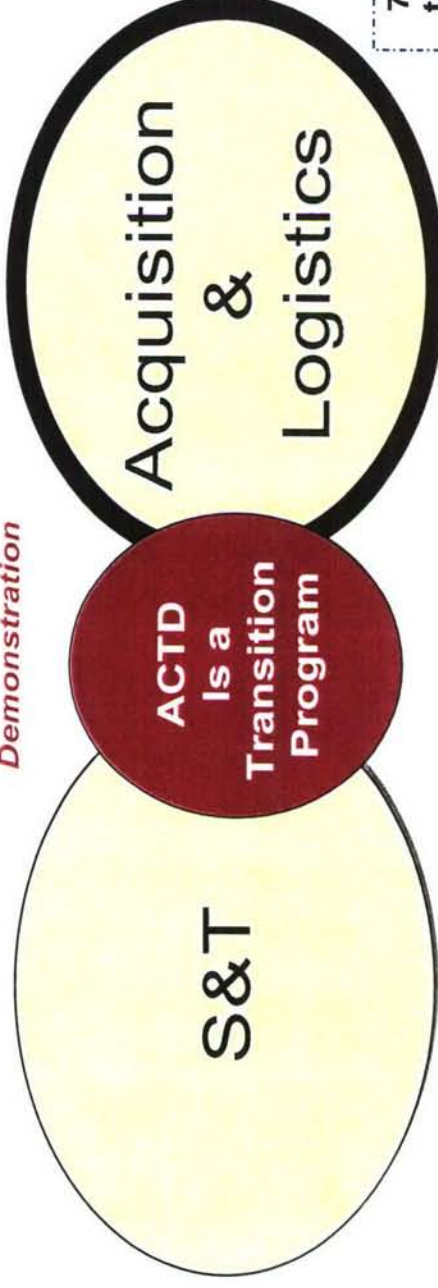
12 April 2005

ACTD Projects Positioned between S&T & Acquisition

Filling the Gap between S&T and Acquisition for the CoCom Customer

Advanced Concept
Technology
Demonstration

“Try before you buy”

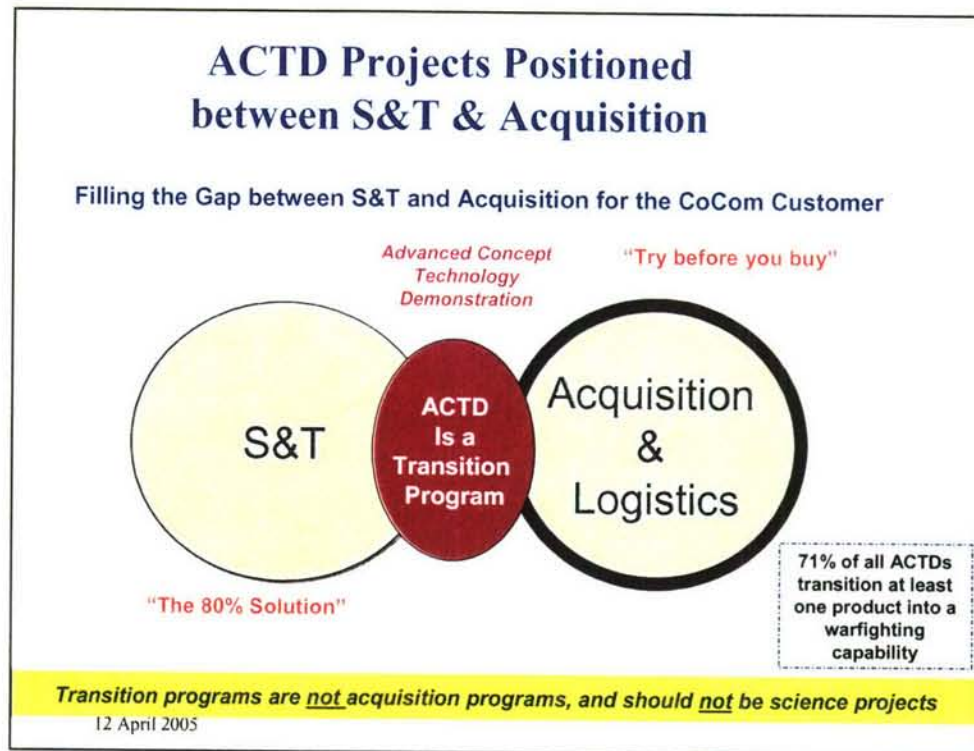


“The 80% Solution”

71% of all ACTDs
transition at least
one product into a
warfighting
capability

Transition programs are not acquisition programs, and should not be science projects

12 April 2005



Mark Peterson
Head, Program Resources & Integration
Deputy Under Secretary of Defense
Advanced Systems & Concepts
www.acq.osd.mil/actd

National Defense Industrial Association (NDIA) Conference

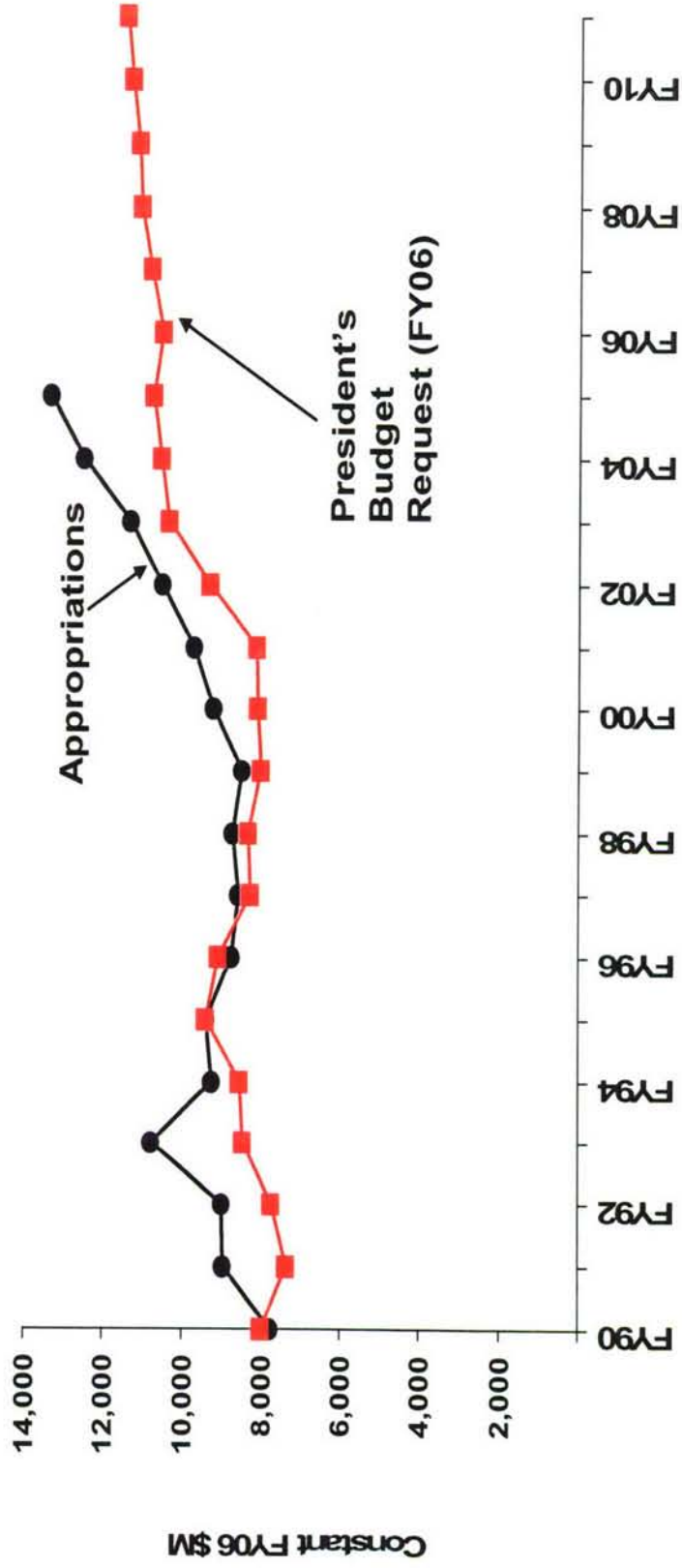
Disruptive Technologies

Frequently Take a Forcing Function

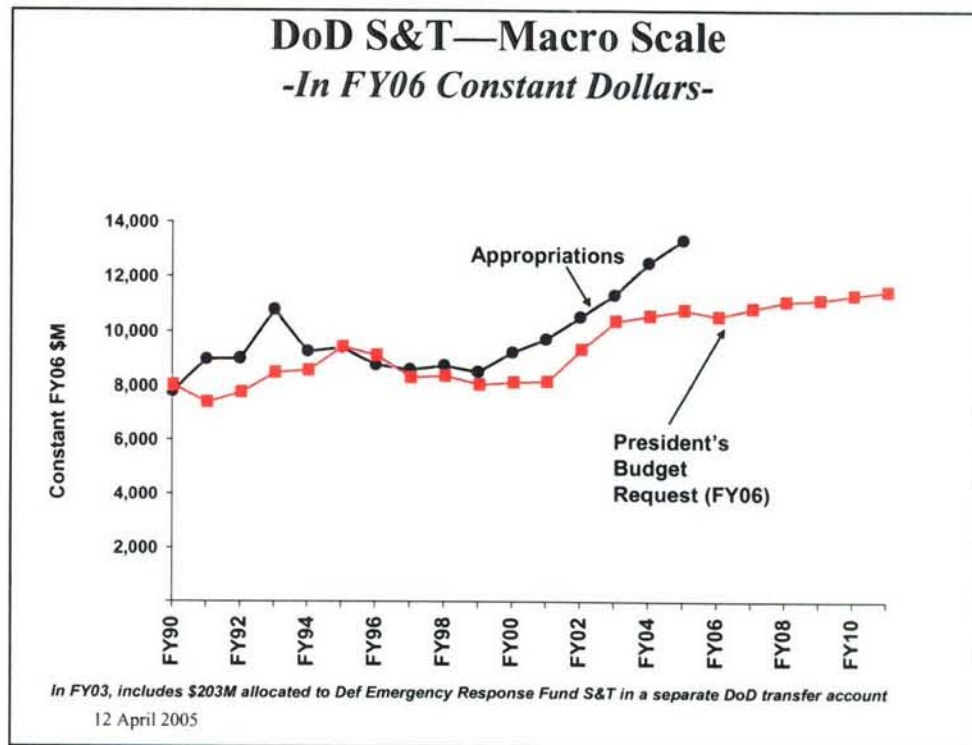
Technology	Approximate Date Of First Lab Demo	Approximate Date of First Military Applications
Radio	1901	1914
Airplane	1903	1916
Vacuum Tube	1906	1915
Mechanized Tank	1916	1916
Liquid-Fueled Rockets	1922	1944
Radar*	1925	1939
Gas Turbine*	1935	1944
Digital Computer*	1943	1945
Ballistic Missile*	1944	1945
Nuclear Weapons*	1945	1945
Transistor*	1948	1957
Inertial Navigation*	1950	1955
Nuclear Propulsion*	1950	1954
Artificial Earth Satellites*	1957	1960
Integrated Circuit*	1960	1970
Laser*	1961	1967
Precision Weapons*	1965	1967
AI Expert System*	1965	1990

12 April 2005

DoD S&T—Macro Scale -In FY06 Constant Dollars-



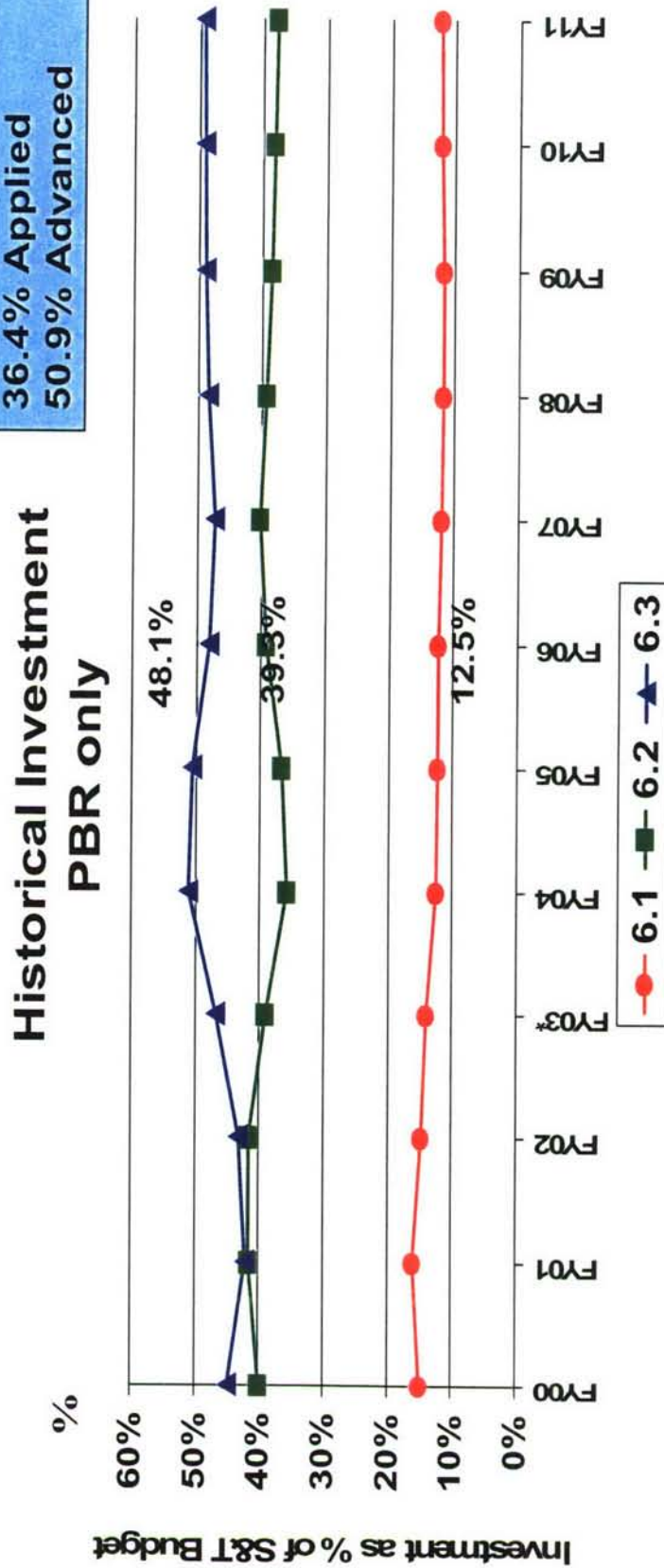
In FY03, includes \$203M allocated to Def Emergency Response Fund S&T in a separate DoD transfer account
12 April 2005



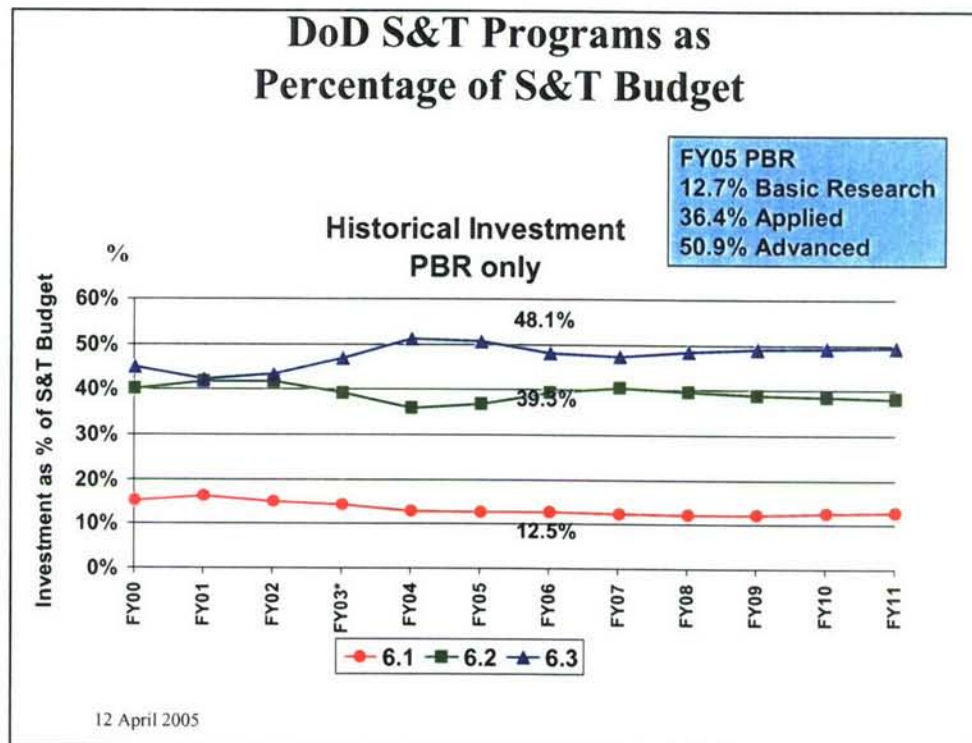
Mr. Robert W. Baker
 April 19, 2005
 Deputy Director, Plans & Programs, ODDR&E
 NDIA S&T Conference.

DoD S&T Programs as Percentage of S&T Budget

FY05 PBR
 12.7% Basic Research
 36.4% Applied
 50.9% Advanced



12 April 2005



Mr. Robert W. Baker
 April 19, 2005
 Deputy Director, Plans & Programs, ODDR&E
 NDIA S&T Conference.

Potential new assertions:

Tanaka:

"The best refuge for out-of-stovepipe ideas is Congress, through plus-ups." Your chart plotting the Navy-requested S&T budget with the Congress-provided S&T budget supports this.

Technical competence requires technical tasking.

For a Warfare Center, as well as for a contractor, skills mix is a result of funded work. It cannot be externally forced in the absence of work. It is not a "procurement" problem.

I would claim that reduced ONR funding to WC's since the 1994/95 abolishment of ONR/OAT has placed more stress on the S&T capabilities of the Navy workforce, has caused a shift in personnel costs to acquisition programs, and has harmed recruiting in a period where recruiting the next generation S&T workforce is critical.

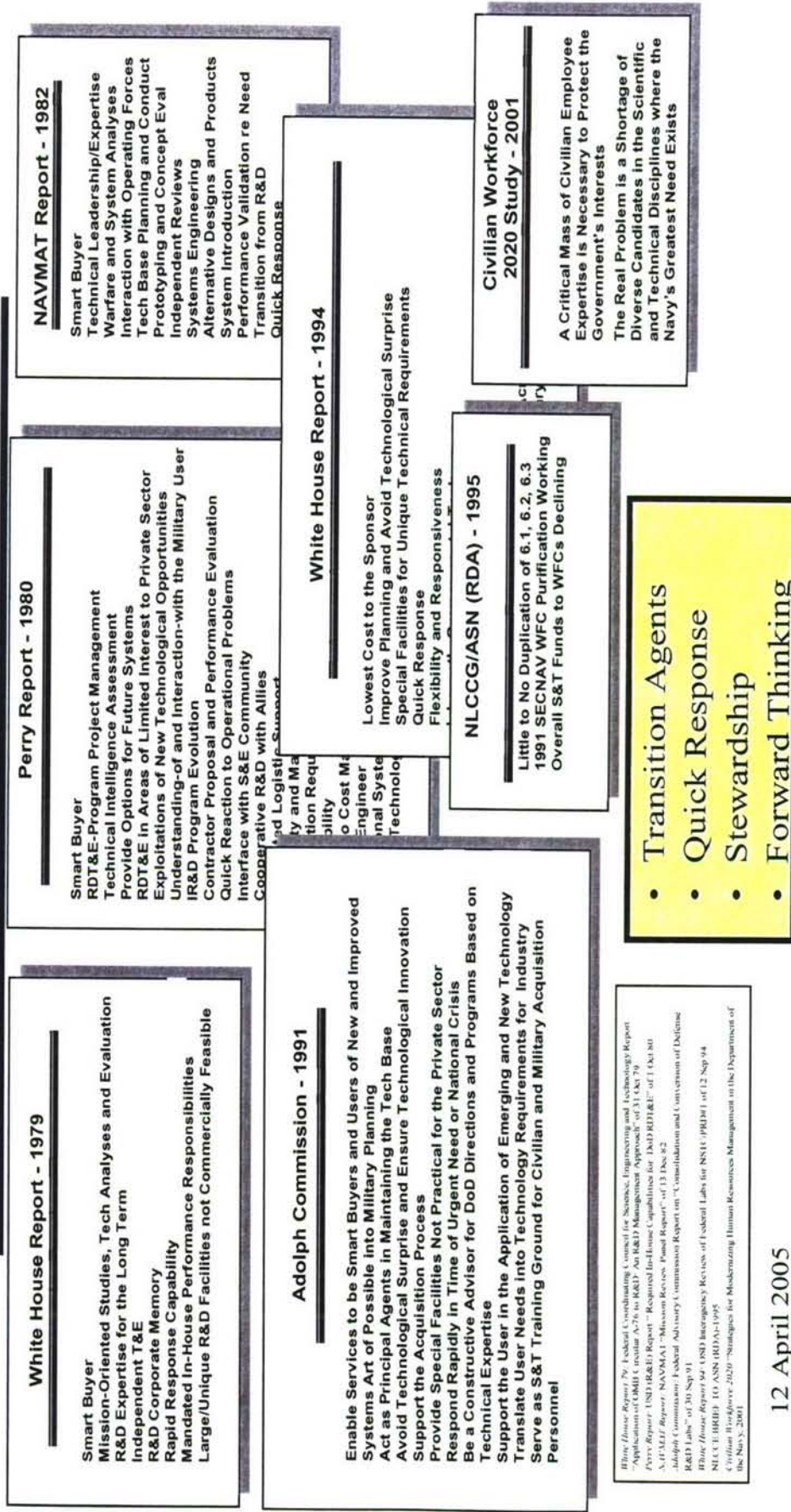
I think the decline can be documented (Mary Lacy and Ira Blatstein, and NAWC did some of this several years ago.) The ONR IAR program and the NSTAR programs provide some evidence that ONR recognizes the problem. Kavetski might provide more evidence.

12 April 2005

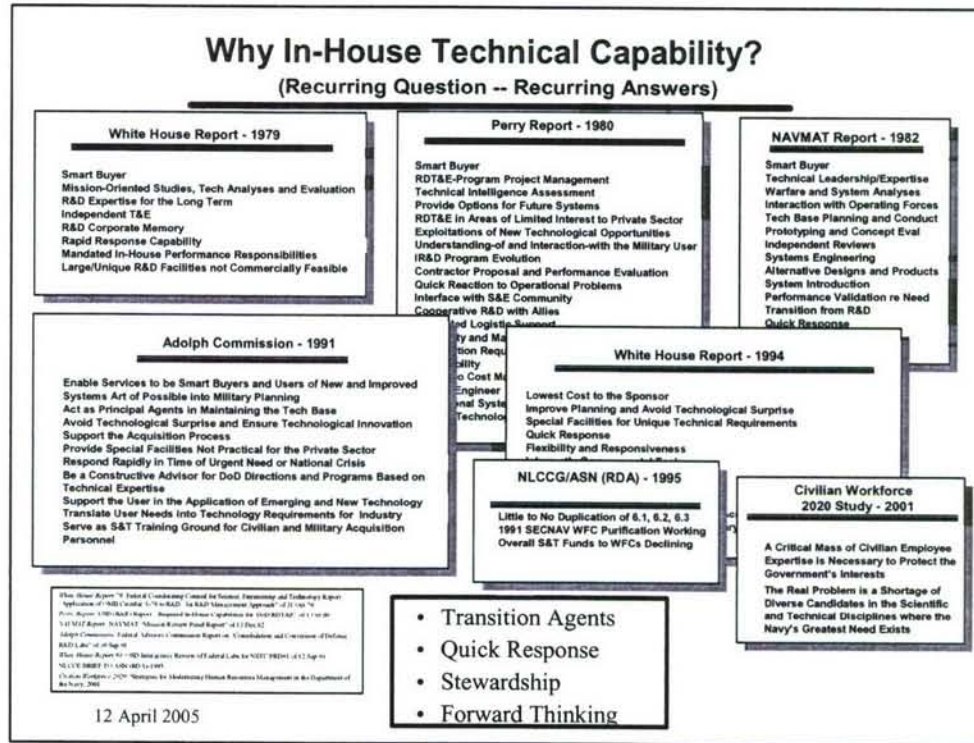
B-143

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Why In-House Technical Capability? (Recurring Question -- Recurring Answers)



12 April 2005



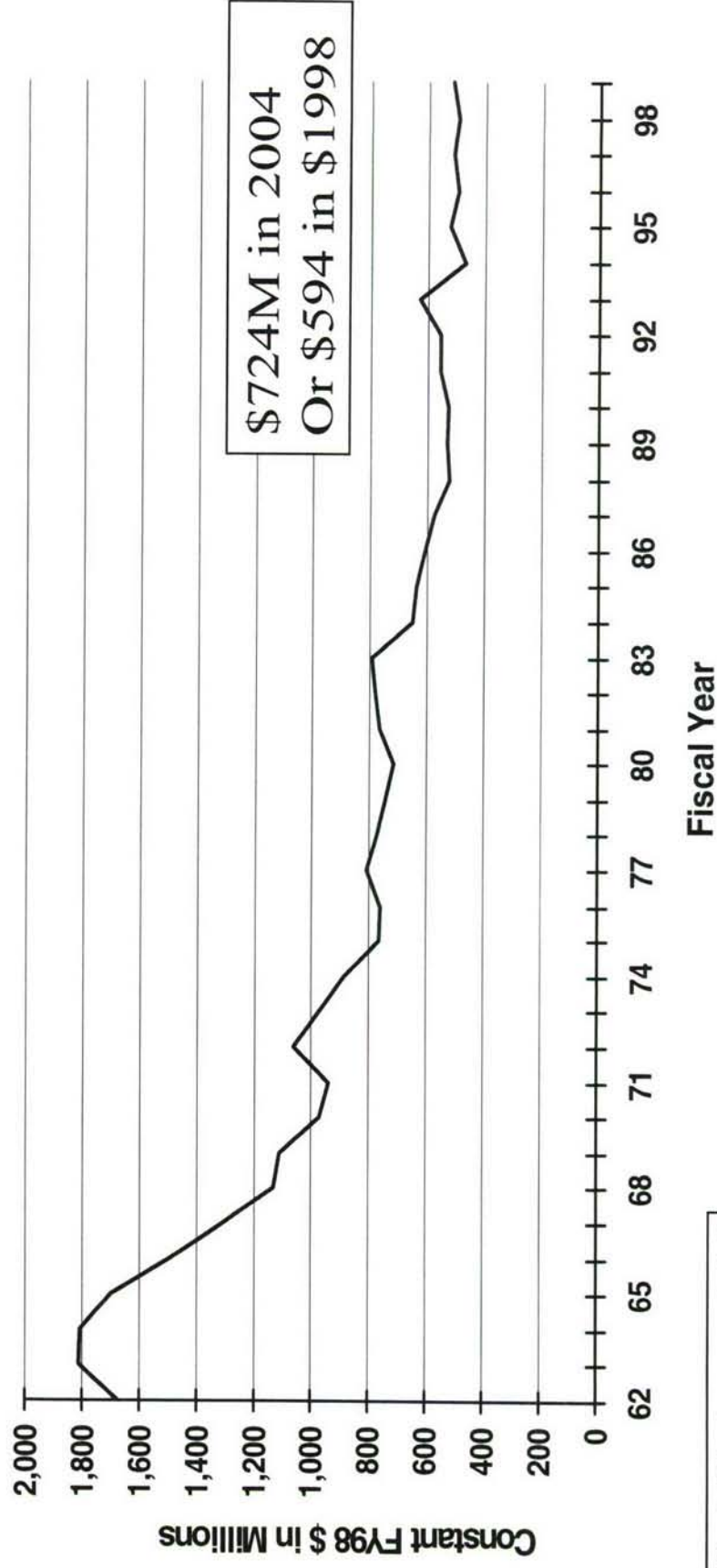
Numerous studies have established the value of Warfare Centers to technology transition and innovation. Mention highlighted areas of common findings.

Most recently, the study conducted by **Hugh Montgomery for ONR**, independently of our study, **resulted in virtually the same conclusions.**

The Hugh Montgomery “Naval S&T Invigoration” draft report references several Defense Science Board reports which contain some elements that support WCs.

- “Efficient Utilization of Defense Labs”, draft Oct 00
 - **Military labs represent an import source of innovation**
- “Technology Capabilities of Non-DoD Providers”, June 00
 - **DoD labs and centers should concentrate on unique military technologies which are crucial to maintaining military preeminence.**
 - **Commercial firms have reduced their long-term technology developments**

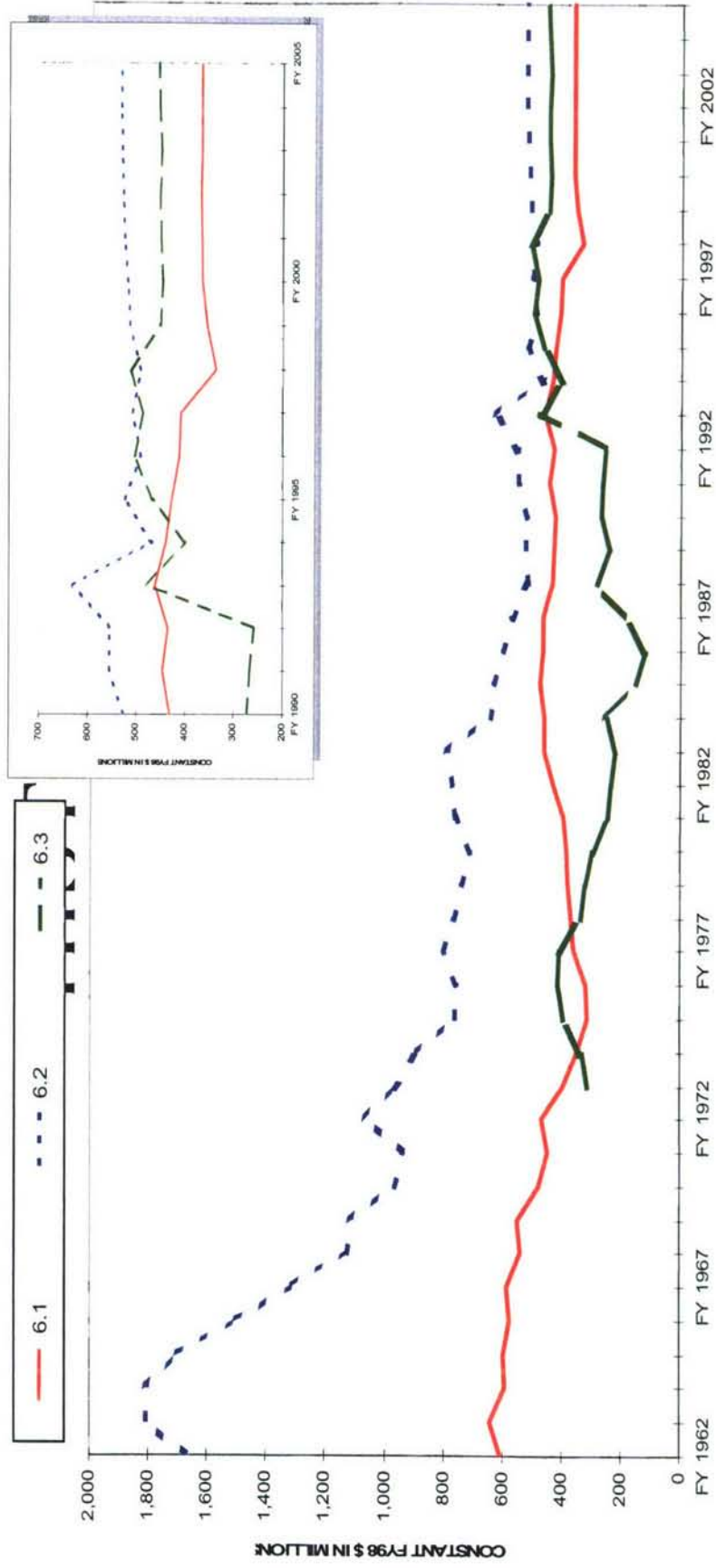
DoN APPLIED RESEARCH (6.2)



Hugh Montgomery brief

http://inflationdata.com/Inflation/Inflation_Rate/InflationCalculator.asp

DoN S&T PROGRAM

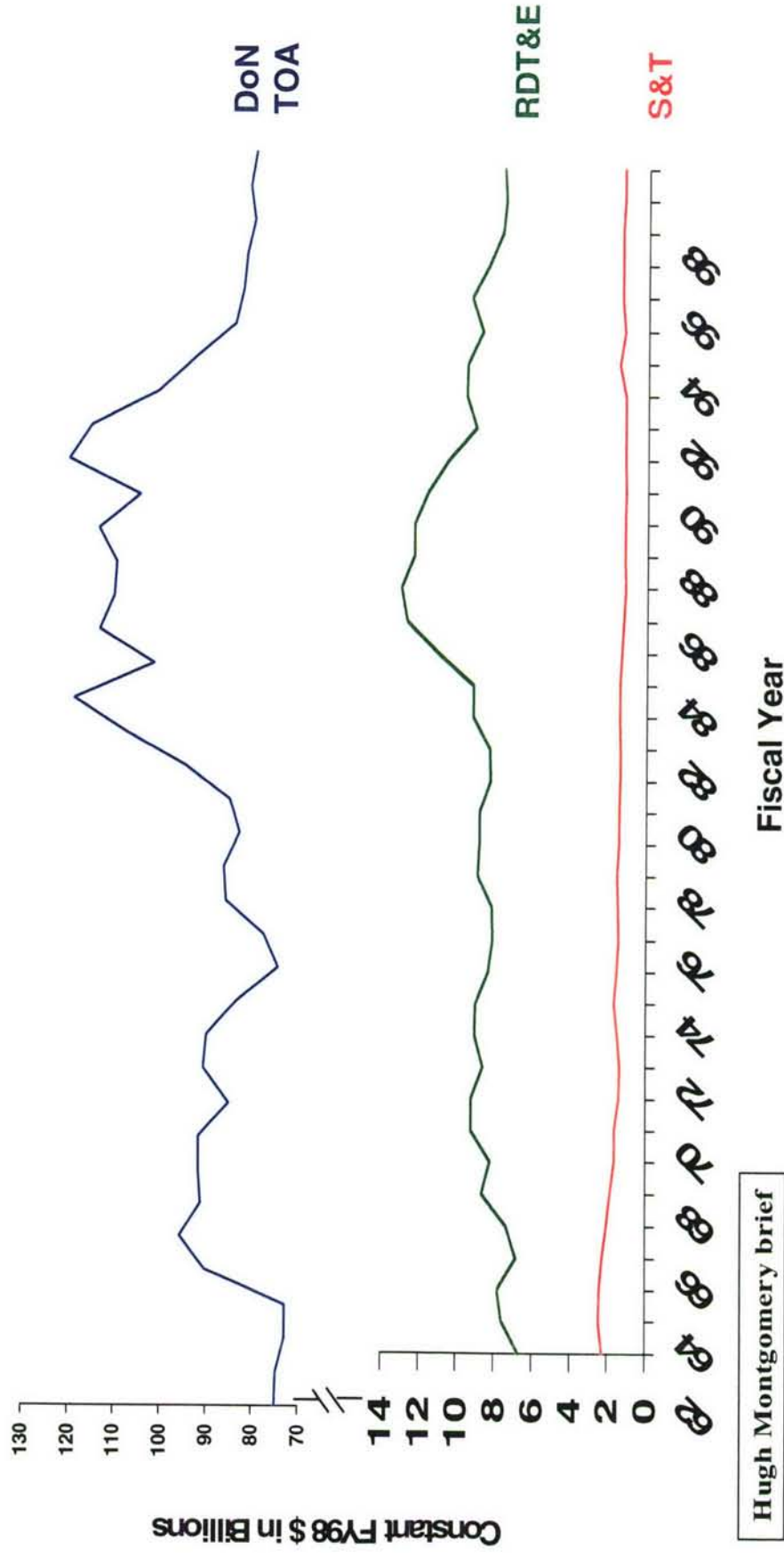


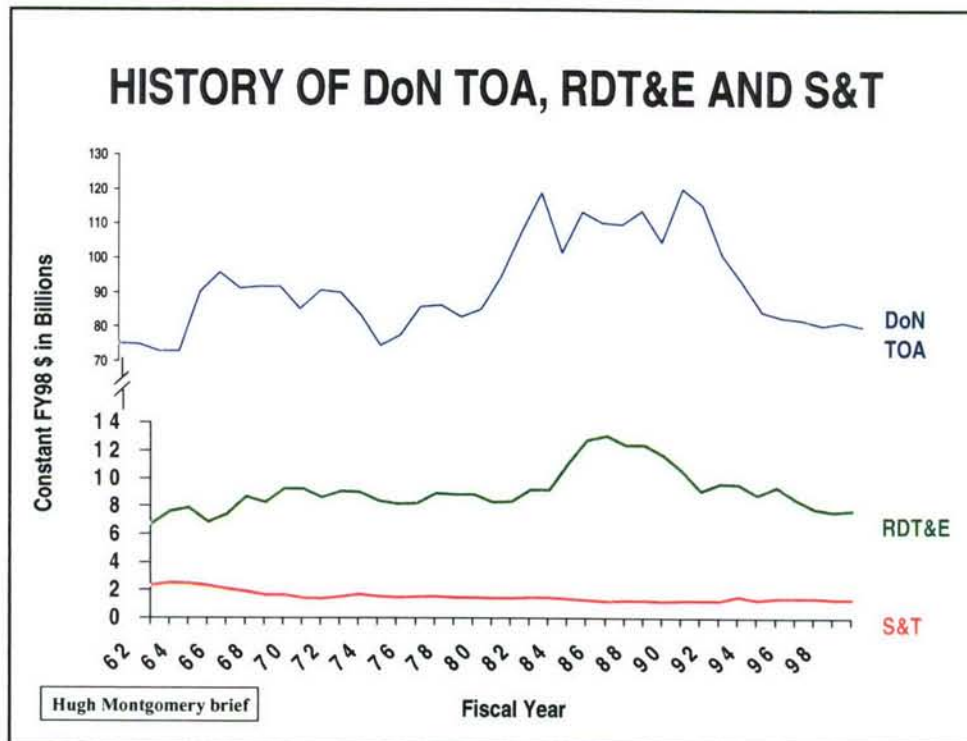
Hugh Montgomery brief

12 April 2005

* FY00 - FY05 do not reflect SPP

HISTORY OF DoN TOA, RDT&E AND S&T



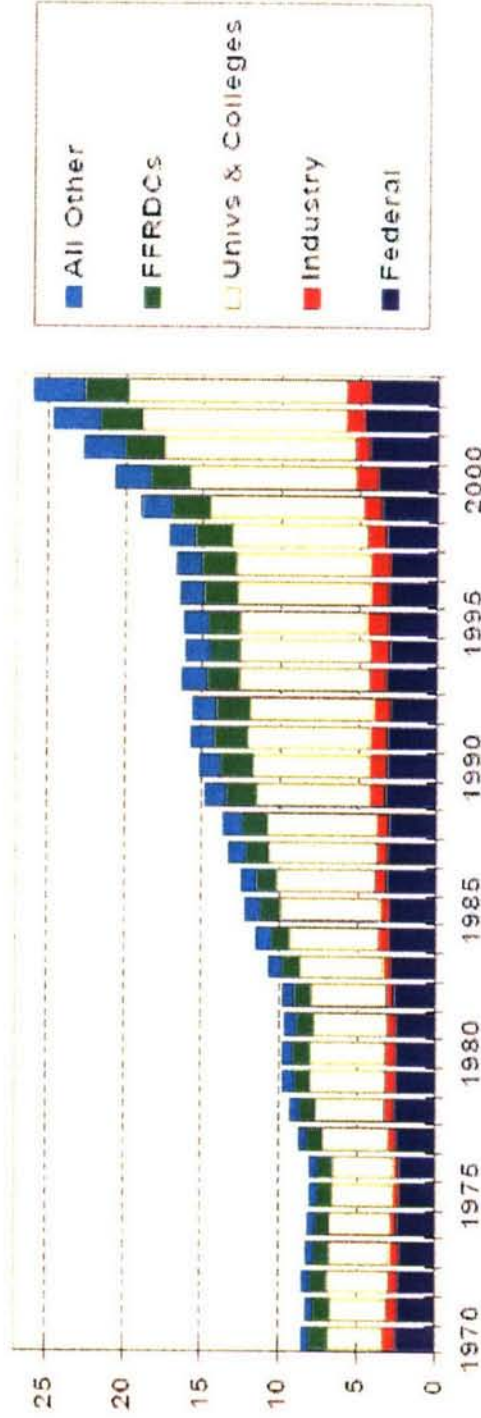


To begin, this is a historical perspective of R&D and S&T funding. Note the break in the axis and the change in scale which is necessary to even get these curves to fit on the same page. Several trends are worth noting. First, the Navy R&D account tends to follow the trend of the Navy Total Obligational Authority or TOA, but, S&T does not. The RDT&E is consistently about 10% of TOA. The S&T portion of RDT&E has stayed relatively constant over the recent past.

The point here is that S&T, as an investment for the future, tends to remain stable, even when TOA is drastically changing; up or down. Today, the Department of Navy's S&T account is about 1.9% of TOA; the lowest of the three services.

Federal BASIC RESEARCH by Performer, FY 1970-2003

Obligations in billions of constant FY 2003 dollars



Source: National Science Foundation, *Federal Funds for Research and Development Fiscal Years 2001: 2002 and 2003 and Federal Funds Historical Tables: 2003*. FY 2002 and 2003 data are preliminary.
AUGUST '03 @ 2003 4.4.4.5

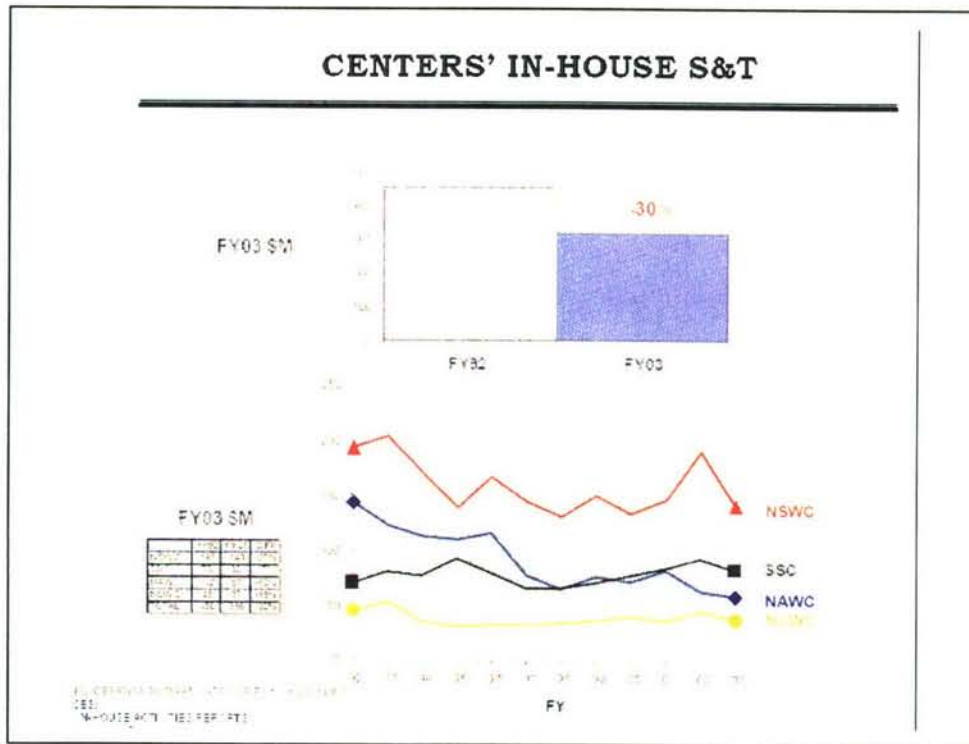
Recent Studies on Federal R&D and S&T

- Science and engineering indicators 2004, National Science Board: <http://www.nsf.gov/sbe/srs>
- Department of Defense In-House S&T activities FY2002 Management Analysis Report: <http://ra.dtic.mil/inhouse> reports
- Vital Assets: Federal Investment in Research and Development at the Nation's Universities and Colleges, Rand: <http://www.rand.org>
- The Science and Engineering Workforce and National Security, Defense Horizons, April 2004
- The Federal Investment in R&D in FY2005 and Beyond, April 2004 for the AAAS S&T Policy Forum: <http://www.aaas.org/spp/ind>

Analysis of the RDT&E and S&T Budgets

12 April 2005

S&T in the NLLCG Community – 6 Oct 2004



“OF the Pentagon's \$419.3 billion budget request for next year, only about \$10.5 billion - 2 percent - will go toward basic research, applied research and advanced technology development.”

“These research and development activities, known as the “technology base” program, are a vital part of the United States defense program. For good reason: the tech base is America's investment in the future. Over the years, tech base activities have yielded advances in scientific and engineering knowledge that have given United States forces the technological superiority that is responsible in large measure for their current dominance in conventional military power.”

“...Of course, the administration and Congress need to make tough budget choices. But to shift money away from the technology base to pay for Iraq, other current military operations or research on large, expensive initiatives, is to give priority to the near term at the expense of the future. This is doubtful judgment, especially at a time when the nature of the threat confronting America is changing. New threats, like catastrophic terrorism and the spread of weapons of mass destruction, urgently call for new technology.”

“...Perhaps the reason for this year's (2006) reduction is the mistaken belief that a one-year gap in financing does not matter, because innovation takes so long. But tech base advances occur because of stable financing. Fluctuating budgets cause wasted effort.”

“...The Department of Defense's technology base programs have been an important factor in giving America the dominant military force in the world.”

New York Times
April 13, 2005
Research Worth Fighting For
By John M. Deutch and William J. Perry

12 April 2005

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NAVY S&T for FY-05

	FY-04	FY05 Pres Bud	FY-05 appro.	% over PB
BA-1	484M	477	496	3.9
BA-2	724	564	826	46.5
BA-3	1009	677	986	45.6

This is the message

Trend: Push to Reduced S&T

FY-05
NAVY 6.1 funding will **increase 2.5%** or \$12 million from \$484 million to \$496 million. The request was \$477 million.
NAVY 6.2 funding will **increase 14.1%** or \$102 million from \$724 million to \$826 million. The request was \$564 million.
NAVY 6.3 funding will be **cut 2.3%** or \$23 million from \$1,009 million to \$986 million. The request was \$677 million.
TOTAL NAVY 6.1, 6.2 and 6.3 funding will increase 4.1% or \$91 million from \$2,217 million to \$2,308 million. The request was \$1,718 million.

DOD Total S&T Budget Numbers

**From the 2006 budget,
Summary Recap of Budget Activities**
Basic Research
Applied Research
Advanced Technology Development

	FY 2004	FY 2005	FY 2006
1,357,988	1,318,775		
4,347,456	4,139,003		
6,184,757	6,707,642		
11,890,201	13,070,676	10,522,127	
	+10%	-20%	
TOTALS			

From the 2005 Budget
Summary Recap of Budget Activities
Basic Research
Applied Research
Advanced Technology Development

	FY 2003	FY 2004	FY 2005
Total	10,728,514	12,081,245	10,550,350

**From the 2004 Budget
Summary Recap of Budget Activities**
Basic Research
Applied Research
Advanced Technology Development

	FY 2002	FY 2003	FY 2004	FY 2005
Total	9,873,558	10,772,627	10,231,161	10,540,562

13 April 2005

The PresBudget has been consistent

Numbers from the official Budget web site for the three Years shown.

12 April 2005

April 6, 2005. Main points ~~on the~~

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DM Giambastiani

From: DARPA Strategic Plan, “Bridging the Gap”, Feb 2005

“As military historians note, None of the most important weapons transforming warfare in the 20th century – the airplane, tank, radar, jet engine, helicopter, electronic computer, not even the atomic bomb – owed its initial development to a doctrinal requirement or request of the military.” *None* of them. And to this list, DARPA would add unmanned systems, stealth, global positioning system (GPS) and Internet technologies.”

John Chambers, ed., *The Oxford Companion to American Military History* (New York: Oxford University Press, 1999) p. 791.

12 April 2005

The National Defense Strategy of the United States of America. March 2005.

Page 3-

Disruptive Challenges. In rare instances revolutionary technology and associated military innovation can fundamentally alter long-established concepts of warfare. Some potential adversaries are seeking *disruptive* capabilities to exploit U.S. vulnerabilities and offset the current advantages of the United States and its partners.

Some *disruptive* breakthroughs , including advances in biotechnology, cyber-operations, space, or directed-energy weapons, could seriously endanger our security.

As such breakthroughs can be unpredictable, we should recognize their potential consequences and hedge against them.

Page 5: **Our Strengths**.

•We will maintain important advantages in other elements of national power – e.g. political, economic, technological, and cultural.

12 April 2005

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The increasing linkage between U.S. technology and public science

Francis Narin, Kimberly S. Hamilton and Dominic Olivastro

CHI Research Inc., 10 White Horse Pike, Haddon Heights, NJ 08035, USA
Available online 10 June 1998.

From the Abstract

A detailed and systematic examination of the contribution of public science to industrial technology would be useful evidence in arguing the case for governmental support of science. This paper provides such an examination, by tracing the rapidly growing citation linkage between U.S. patents and scientific research papers. Seventy-three percent of the papers cited by U.S. industry patents are public science, authored at academic, governmental, and other public institutions; only 27% are authored by industrial scientists.

12 April 2005

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TRANSFORMATION'S TRAJECTORY

Art Cebrowski, former director,
Office of Force Transformation
3 March 2005

“R&D is really quite nuanced. There is a texture to it. How much money are you going to allocate to reinforce decisions already made in the past? For example, if you decide you are going to do a Joint Strike Fighter and it develops a problem in development you may have to put some significant money against it. This is money that has to come from somewhere else in the R&D accounts. Perhaps by cutting money earmarked for university research? Possibly by reducing funding for defense labs. More importantly, however, what is being shortchanged is the process of discovery and invention. As the department moves into a period of uncertainty, discovery and invention are increasingly important.”

“The department must look at the economics of R&D from a strategic point of view. The great power of America is really our human capital—our brainpower. Historically, when money is moved into certain research areas, there is a mirror image movement in the percentage of PHD candidates in those areas of emphasis. It is an indication of the strategic power of R&D. But, if the department is spending a disproportionate share of precious R&D by shoring up decisions previously made, we are losing some of that strategic power. In times of uncertainty, especially, this is what is going to ultimately give us the breadth of development to make decisions on relatively short timelines.”

12 April 2005

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National Innovation Initiative –
Public Sector Innovation Working Group Report (date
received – 8 Mar 2005, no date shown on the report.)

<http://www.compete.org/docs/pdf/NIIPublicSectorFinal%20Report.pdf>

The Public Sector Innovation Working Group focused its final recommendations on innovating health care delivery, making the public sector more innovative, and investing in long-term research uniquely suited for government.

(A) Address National Priorities through Mission-driven Network Infrastructure:

1st Priority -- Health Care

(B) Enact a Public Sector Innovation Act: Competition and Performance-based Services and an Innovative Federal Workforce

(C) Pursue Our Children's Prosperity and Security through Long-term Research (Raise long-term research supported by the Defense, Energy, and National Science Foundation budgets to at least 1 percent of GDP.)
(2004 GDP was \$11,733.5 B)

<http://www.aas.org/spp/rd/fy06.htm> resource for 2006 numbers.
DOD = \$10.7B, DOE = \$3.2B, NSF = \$5.6B Total= \$19.5B

THE TASK FORCE
ON THE FUTURE OF AMERICAN INNOVATION
Innovation is America's Heartbeat
www.futureofinnovation.org
THE KNOWLEDGE ECONOMY:
IS THE UNITED STATES LOSING ITS COMPETITIVE EDGE?
BENCHMARKS OF OUR INNOVATION FUTURE
February 16, 2005

1. This report restates the 1% GDP recommendation from the Dec 2004 Council on Competitiveness report.
2. As the Hart-Rudman Commission on National Security stated in 2001: *...[T]he U.S. government has seriously underfunded basic scientific research in recent years... [T]he inadequacies of our systems of research and education pose a greater threat to U.S. national security over the next quarter century than any potential conventional war that we might imagine. American national leadership must understand these deficiencies as threats to national security. If we do not invest heavily and wisely in rebuilding these two core strengths, America will be incapable of maintaining its global position long into the 21st century.*²

In the post-9/11 era especially, we should heed this warning.

www.futureofinnovation.org

12 April 2005

Carly's Way - selected excerpts
As Told to Michelle Delio **March 4, 2005**
Technology Review

Carly was a marketing person put in charge of engineers, a person who cared **nothing about the art and beauty of technology. She just wanted saleable stock to bring to market.**

Our biggest mistake at HP Labs came from being too cautious. ...every project needed to make a profit within three years or less.

In mid-2002, HP's labs became solely focused on finding ways for other businesses to save money .

Research almost always benefits an entire industry more than any particular company. And research doesn't have immediate results.

Research is expensive and unpredictable. Things that today's business world frowns on.

The damage to HP and the U.S. technology industry at large may already be irreversible.

If we start investing today and let our engineers play we might have something exciting to show people in 2010. That's a long time to wait for the next big wow.

To me, this rabid fixation on short-term profits is a bigger threat than outsourcing -- it is killing our ability to make astonishing things.

12 April 2005

Necessity: Mother of Development

Microsoft's Advanced Technology Center (ATC), opened in November 2003, takes up half of one floor of a six-floor office building in the Haidian district of northwest Beijing—the same edifice occupied by Microsoft Research Asia, one of six research labs worldwide that Microsoft operates. **Enhancing the transfer of technology** between the 170-strong research facility and product development groups at Microsoft's headquarters in Redmond, WA, is the whole reason the center exists, and the close proximity to the lab makes handoffs easier.

Zhang, who worked on technology transfer at Hewlett-Packard Labs before being recruited as a charter researcher at the Beijing lab, says the issues spurring the ATC's creation are common to all research and development-driven organizations. After researchers hand off an invention or a new piece of code to product developers, a lot of refinement and testing is needed to get it ready for commercial release, and the product developers aren't always able to do it. They often have their hands full with more pressing jobs—say, upgrading conventional features or improving security. And even a great invention might arrive at the wrong point in the product development cycle, where it's difficult to fit into the next release. "Which means that for the product group to form a team and take that risk [of developing the invention] may be too big a risk and too big a distraction," says Zhang.

"Microsoft: Getting from R to D"

12 April 2005

From Stuart Moran

I found an article written in spring 2002 for Aerospace Power Journal by a Lt. Colonel Suddarth in the Air Force.

The Editorial Abstract reads:

Why has the Air force lost the lead in technology development that it held over industry in the 50s and 60s.? Colonel Suddarth believes we can find the answer in the shift in emphasis from product to process management that began in the early 60s. Since that time, the Air Force has moved from the simple management of complex systems to the complex management of simple systems---and has gained little in the process.

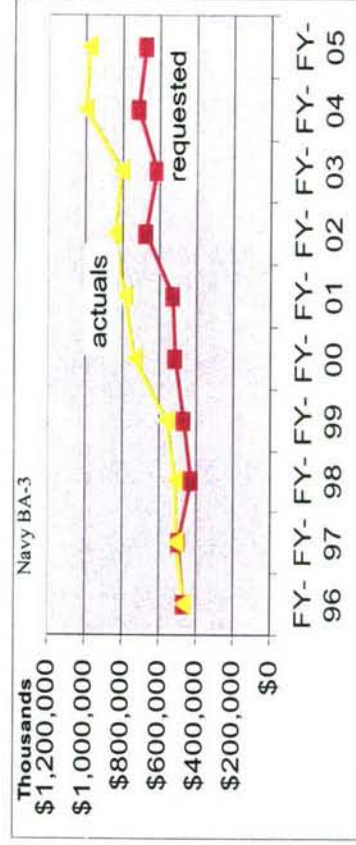
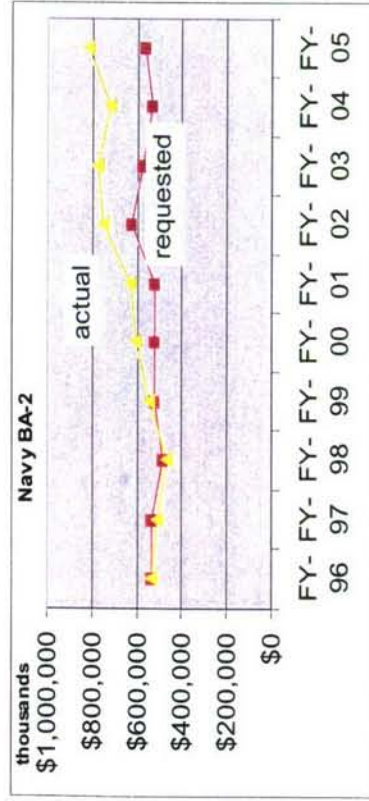
I thought that was a good statement. - Stuart Moran

12 April 2005

. "We are fond of talking about the asymmetric advantages the enemy has, but ours is the genius of our people, this intellectual capital," Clark said. "It is about the ability to field the most incredible technologies the world has ever seen."

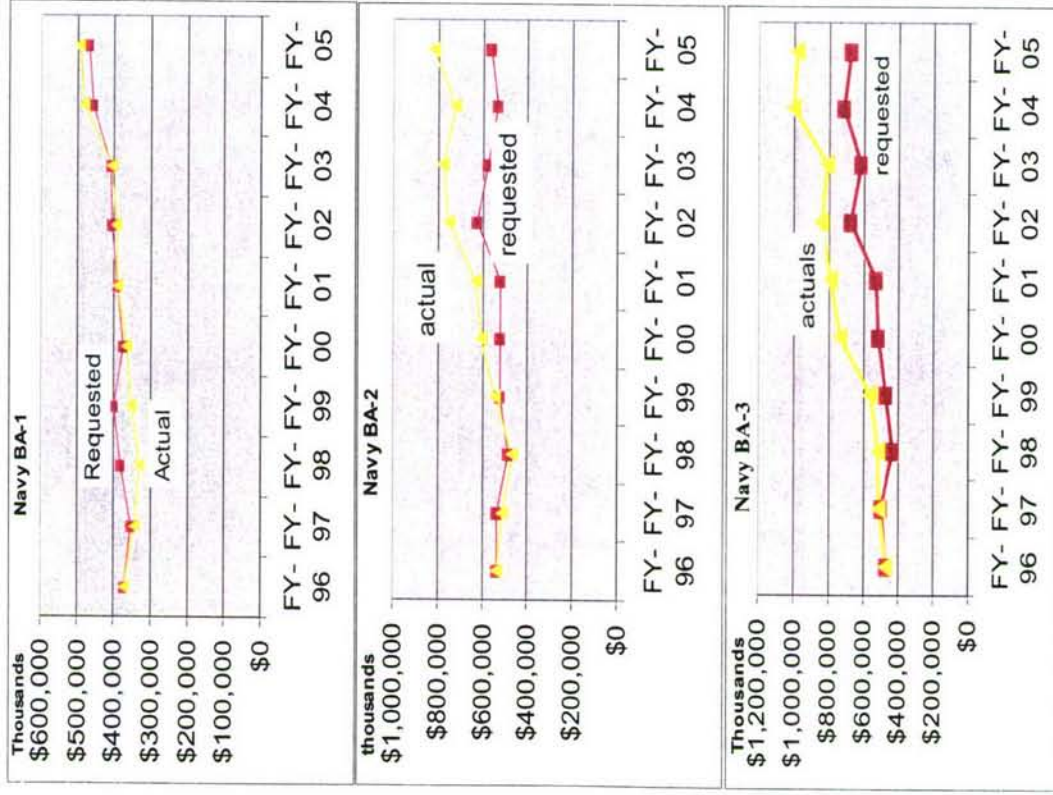
Adm. Vern Clark told the Force Net 2005 symposium in Alexandria, Va., on

Monday 7 February 2005.



12 April 2005

Inherent value (performance and productivity) of the scientific and engineering workforce



Navy S&T funding data. Actual and requested.

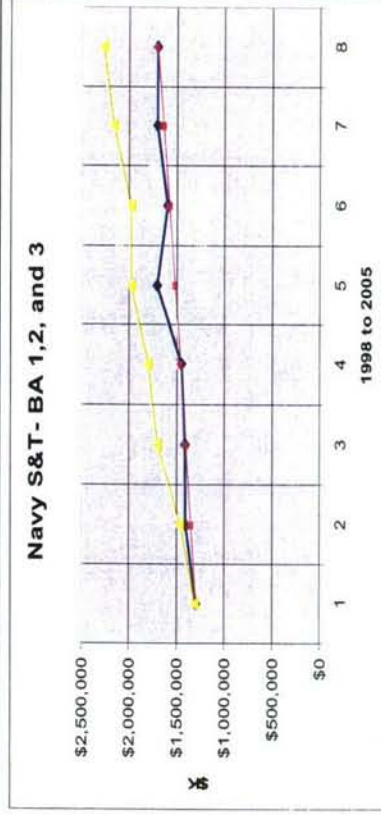
Except for BA-1, recent years indicate a policy to decrease funding, while congress is increasing it.

	FY04	FY05 Pres Bud	FY05 appro	% over PB
BA-1	\$484 M	477	496 +2.5%	3.9
BA-2	\$724 M	564	826 +14%	46.5
BA-3	\$1009 M	677	986 -2.3%	45.6

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Monday 7 February 2005.



This is generally true of DOD S&T.

12 April 2005

Thoughts from Headquarters

28 July 2004

One of the issues that continues to plague all of the Warfare Centers is one of metrics. We have been struggling to find that right way to measure the effectiveness of what we do. The CNO would love to have something to gauge the return on investment for the Warfare Centers. Obviously it is difficult to measure ideas and even more difficult to measure how those ideas impact the Fleet directly. As a group the Warfare Centers have pooled their thoughts and we are proposing to track the reliability of 8 major systems. We have developed a graphic way to display the information so that whoever views the data will get an immediate feel for the reliability of a system and of how that system compares with the other 7. We don't know for sure if this will give us meaningful results or not but we're going to try it for a period to see if it is useful.

12 April 2005

FLASH! The CNO says...

Aerospace Daily & Defense Report
January 12, 2005

Navy Not 'Correctly Balanced' For Future, Clark Says

The Chief of U.S. Naval Operations, Adm. Vern Clark, said Jan. 11 that the Navy is not "correctly balanced and optimized for the world of the future," and that it faces a three-decade-long effort to fully reform its forces to accommodate national security needs such as anti-terrorism and homeland security. Reiterating his call for a "new strategic construct" for the Navy, Clark said the days of major naval engagements are past - at least for now - and that concerns such as missile defense and close-shore operations are driving structural changes in Navy force sets.

"Building a force set that is designed only to deal with ... major combat operations ... is the incorrect approach," he said in the keynote address to the Surface Navy Association's national symposium in Arlington, Va.

Instead of pulling from its major-combat operations force set for smaller operations such as peacekeeping and stability operations, the Navy should have whole force sets that address those needs, Clark said.

He pointed to tsunami-relief efforts and military operations in Iraq and Afghanistan as examples of the Navy's near future missions. Clark also noted the Sea Power 21 vision, which is transforming the way the Navy fights, in refining the service's battle against terrorism.

The CNO also said he is prepared for a tougher appropriations process on Capitol Hill this year. Although Congress will not receive the fiscal 2006 defense budget until early February, possible naval cuts already have been leaked (DAILY, Jan. 4). Funding could be reduced for the Navy's aircraft carriers, DD(X) destroyer, LPD-17 ship, Virginia-class submarine and the Marine Corps' Expeditionary Fighting Vehicle.

Where once he believed the country should work toward 375 Navy ships, new methods and technologies such as "sea swapping" crews among ships at sea have led Clark to re-evaluate even that number. "We're not walking around with our heads in the sands," he said.

-- *Michael Bruno*

If this, then:

Navy S&T should be refocused to address this new future. This is not the time to reduce S&T investment, but it is the time to begin preparations to meet these new challenges.

12 April 2005

At no time since the eleventh century has the scientific influence of the Islamic world been equal to what it enjoyed the preceding four centuries. The late Pakistani physicist Abdus Salam, the first Muslim ever to win the Nobel Prize, lamented:

There is no question [that] of all civilizations on this planet, science is the weakest in the lands of Islam. The dangers of this weakness cannot be overemphasized since honorable survival of a society depends directly on strength in science and technology in the conditions of the present age.

12 April 2005

**** “Michael Wynne, acting under secretary of defense for acquisition, technology and logistics, warned of dire consequences if the workforce pattern continues. “We really want to remain the beacon to the world on science and technology,” Wynne said in the statement. “We feel like that may be at risk.” “**

****Dec. 23, 2004, Inside Defense.com -- Earlier this month, Pentagon and defense industry officials attended a National Defense Industrial Association workshop to devise a strategy for attracting more workers to the aerospace industry.**

12 April 2005

**6. S&T projects never go according to plan.
Cont.**

“Without some individual or institutional accountability of university researchers to the Technology Area Reviews and Assessments process, the allocation of funds through peer-reviewed grants will not meet all the needs of our defense basic research program. This is evidenced by the fact that from FY97 to FY02, 181 MURI projects have been funded, and **none of them has transitioned technology to the warfighting force.**²⁰ “*

Multidisciplinary University Research Initiative (MURI)

12 April 2005

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Cont.**

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Multidisciplinary University Research Initiative (MURI)

12 April 2005

*Fountain page 45/46

Rep. Vern Ehlers (R-MI) spoke about the NSF funding level in H.R. 4818, stating:

Re:
FY 2005 budget

"While I understand the need to make hard choices in the face of fiscal constraint, I do not see the wisdom in putting science funding far behind other priorities. We have cut NSF despite the fact that this omnibus bill increases spending for the 2005 fiscal year, so clearly we could find room to grow basic research while maintaining fiscal constraint. But not only are we not keeping pace with inflationary growth, we are actually cutting the portion basic research receives in the overall budget." He continued, "This decision shows dangerous disregard for our nation's future, and I am both concerned and astonished that we would make this decision at a time when other nations continue to surpass our students in math and science and consistently increase their funding of basic research. We cannot hope to fight jobs lost to international competition without a well-trained and educated workforce. If we want to remain competitive in the international marketplace, we must provide funding that stimulates innovation and supports education. Within our borders, NSF supports technological innovation that has been, and remains, crucial to the sustained economic prosperity that America has enjoyed for several decades. This innovation is made possible, in large measure, by NSF support of basic scientific research, particularly in the physical sciences. Research at NSF not only underpins physical science research, but lays the foundation for work in the health sciences and medicine as well. Reducing this funding is extremely short-sighted."

12 April 2005

Example of a Bad Objective – or Metric

National Institute for Occupational Safety and Health (NIOSH)

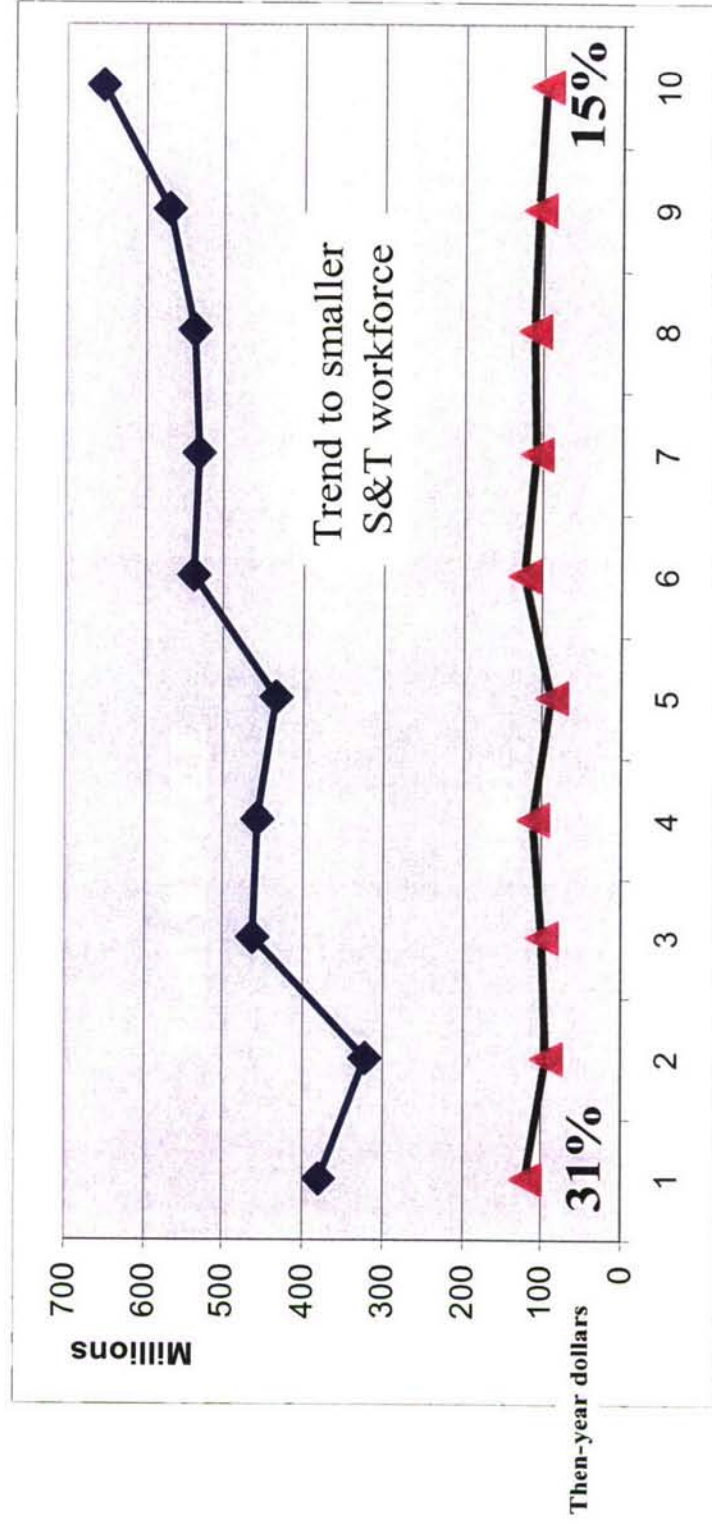
Objective: “Conduct a targeted program of research to reduce morbidity, injuries, and mortality among workers in high-priority areas and high risk sectors.”

Comment: How will this be measured? Morbidity and mortality are downstream outcomes, not subject to managing. NIOSH is to be evaluated by factors out of its control. Much of the responsibility for reducing mortality and morbidity lies with industry’s compliance with safety and health regulations.

The ultimate achievement of NIOSH strategic goals “*depends on the actions of S&T users.*”

12 April 2005

S&T At Dahlgren Division

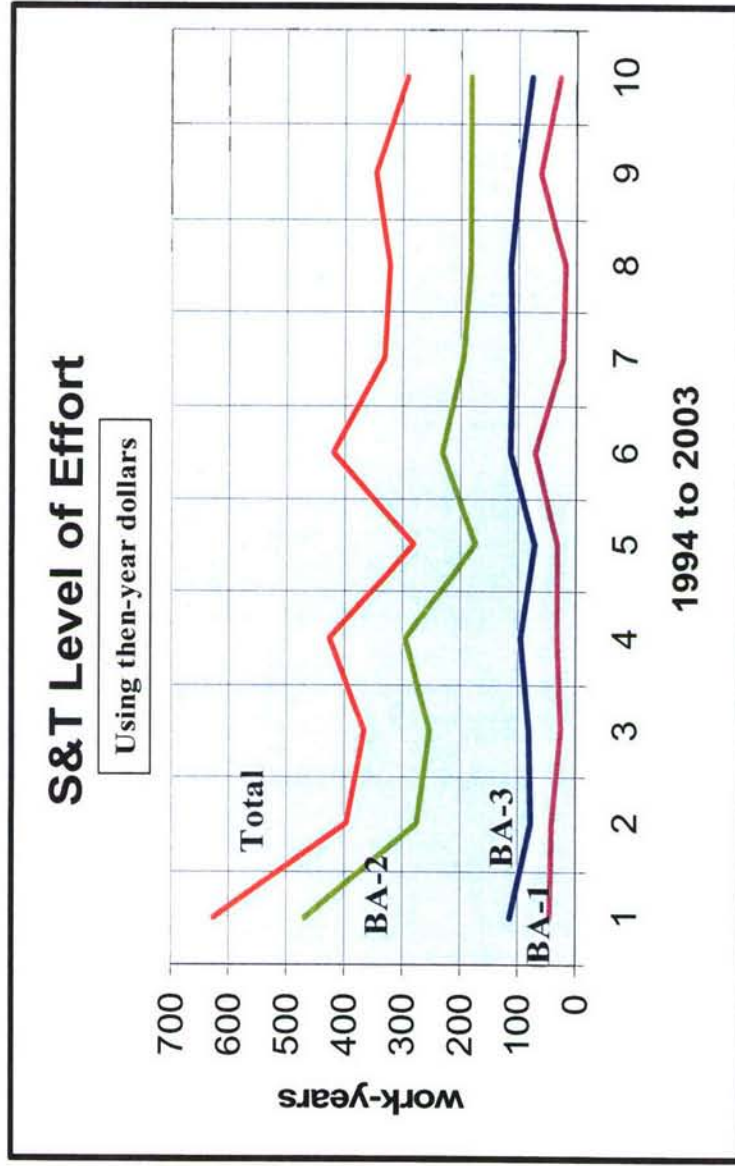


From 1994 to 2003
Budget Activities 1, 2, and 3.

BA 1: Basic Research
BA 2: Applied Research
BA 3: Adv. Tech Development

12 April 2005

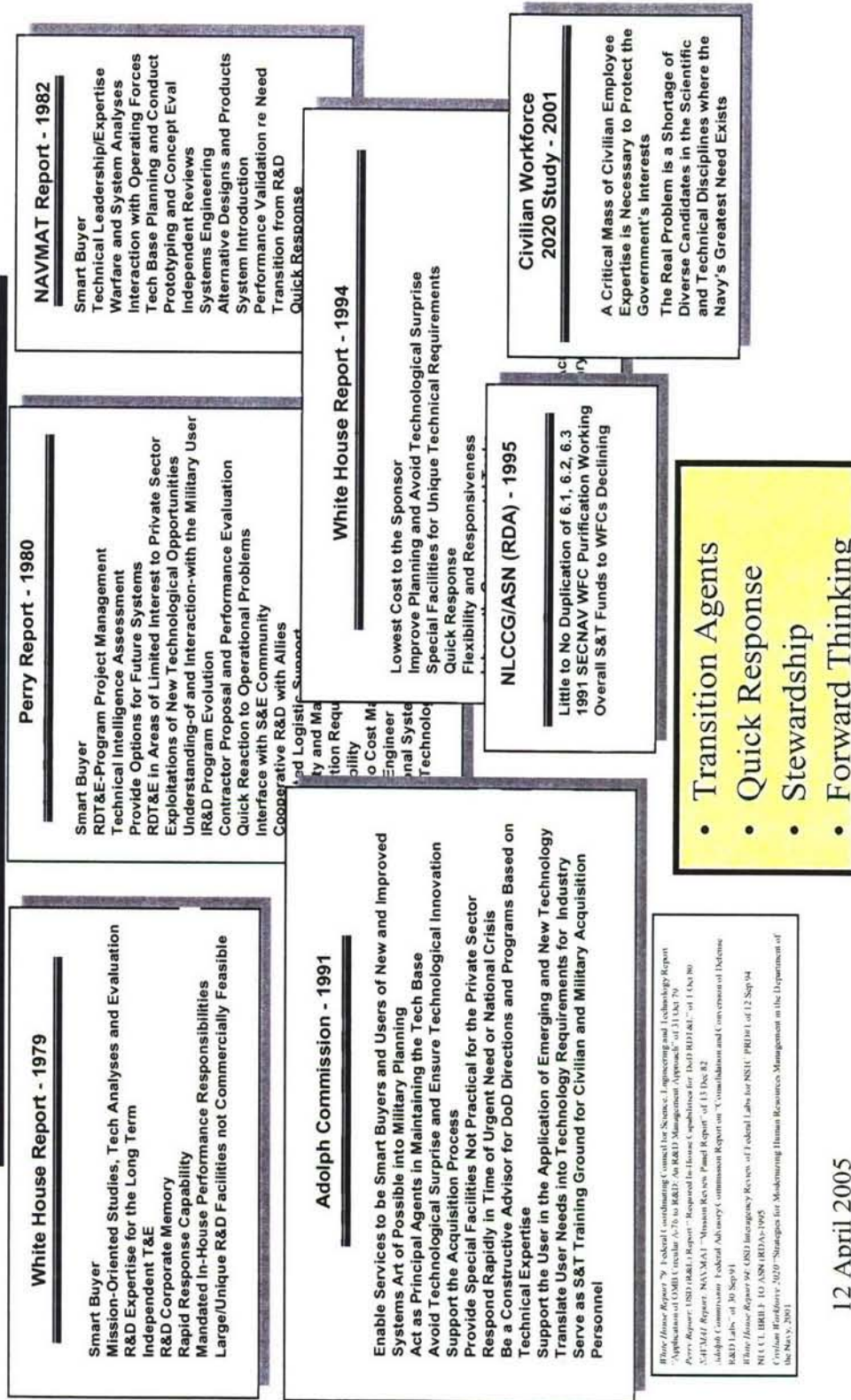
Dahlgren Data



Trend is in wrong direction.

12 April 2005

Why In-House Technical Capability? (Recurring Question -- Recurring Answers)



12 April 2005

Warrant Holders Supported

Chief Systems Engineer	6 Amphibious and Auxiliary Ships Warfare Systems	REYNOLDS	HARRY	J
Chief Systems Engineer	6 CV/CVN 68-77 Class Warfare Systems	DEATON	WILLIAM	A
Chief Systems Engineer	6 CVN 21 Class Warfare Systems	DEATON	WILLIAM	A
Chief Systems Engineer	6 DD(X) Class Warfare Systems	PARKER	STEPHEN	W
Chief Systems Engineer	6 DDG51/CG 47 Class Warfare Systems	MURPHY	DAWN	F
Chief Systems Engineer	6 LCS Class Warfare Systems	RIVERA	MIGUEL	E
Chief Systems Engineer	6 MCM/MHC Class Warfare Systems	TUBRIDY	DAVID	B
Technical Area Expert	6 Combat Systems ISE for MCM/MHC Class	BURCH	GEORGE	W
Technical Area Expert	6 Mine Countermeasures	TUBRIDY	DAVID	B
Technical Area Expert	6 Mines	TUBRIDY	DAVID	B
Technical Area Expert	6 Radar, IR, RF and EO Sensors (except Submarine Systems)	KOCH	STUART	A
Technical Area Expert	6 Surface Ship Combat and Weapons Control	SCARAMOZZI	TONY	D
Technical Area Expert	6 Surface Ship Electronic Warfare Systems	STELLO	SAMUEL	L
Technical Area Expert	6 Surface Ship Guns	TSCHIRN	THOMAS	N
Technical Area Expert	6 Surface Ship Launchers	MILLER	KEITH	K
Technical Area Expert	6 Surface Ship Missiles	MILLER	KEITH	K
Technical Area Expert	6 Unmanned Surface Vehicle Systems	SANTORA	GUY	A

My Conclusion so far: The TWHs are still trying to define their respective pyramids.

12 April 2005

Clarification of Terminology Science and Technology (S&T)

Based on actions, not color of funding.

Technology Readiness Levels (DoD 5000 Draft)

S&T

1. Basic principles observed and reported. paper studies
2. Invention begins – speculative - no proof or detailed analysis to support the assumption
3. Research and development is initiated - studies to validate predictions
4. Component and/or breadboard validation
5. Component and/or breadboard validation with reasonably realistic supporting elements
6. System/subsystem model or prototype
7. Prototype demonstration near or at planned operational system.
8. Actual system completed and "flight qualified" ---represents the end of true system development.
9. Actual system "flight proven" under mission conditions

12 April 2005

Transition is recognized between all TRL levels.

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9. Actual system "flight proven" under mission conditions

12 April 2005

Transition is recognized between all TRL levels.

The information on DoD 5000 rewrite came from a briefing, the title page of which is given here.

DoD 5000 Rewrite

brief for

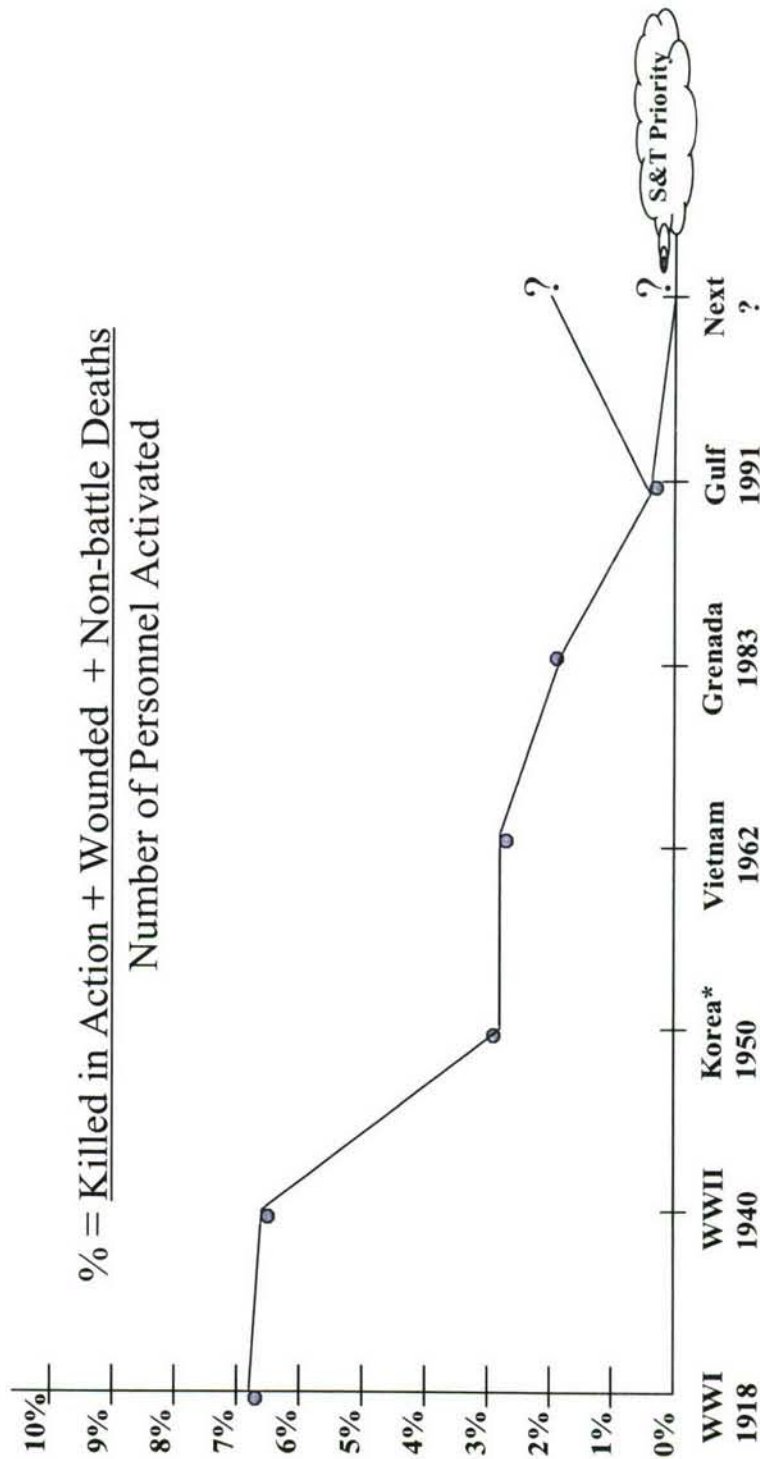
Deputy Assistant Secretary of the Navy (Air)

Denis Catalano
Director, NAVSEA Acquisition Support Office
&
Chairperson, ASN(RD&A) ABM 5000/
Deskbook Working Group

7 Sept 2000

Combat Casualties

The Future



Source: Army History Office

* Non-battle deaths estimated

12 April 2005

ILIR data

Output	1993	1994	1995	1996	1997	1998	1999	2000	2001
# "Transitions"	No Data	38	35	41	33	38	44	49	50
# Projects (~# PIs, not FTEs)	181	197	218	214	206	192	183	195	198
Published Papers	393	270	259	225	250	261	270	202	203
Submitted Papers	110	90	82	74	59	17	19	54	109
Books/Chapters	52	7	20	19	6	8	13	16	8
Patents/Patent Applications	79	67	69	72	93	98	99	105	94
Government Reports	76	62	68	56	38	27	20	8	19
Dissertations	37	10	13	5	3	1	6	5	3
Presentations	417	259	369	248	248	234	234	229	220
Awards/Honors	79	52	68	39	41	39	48	19	14
Funding (M)	\$15.4	\$16.8	\$17.0	\$15.0	\$13.7	\$13.1	\$13.0	\$14.2	\$14.4

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ILIR data

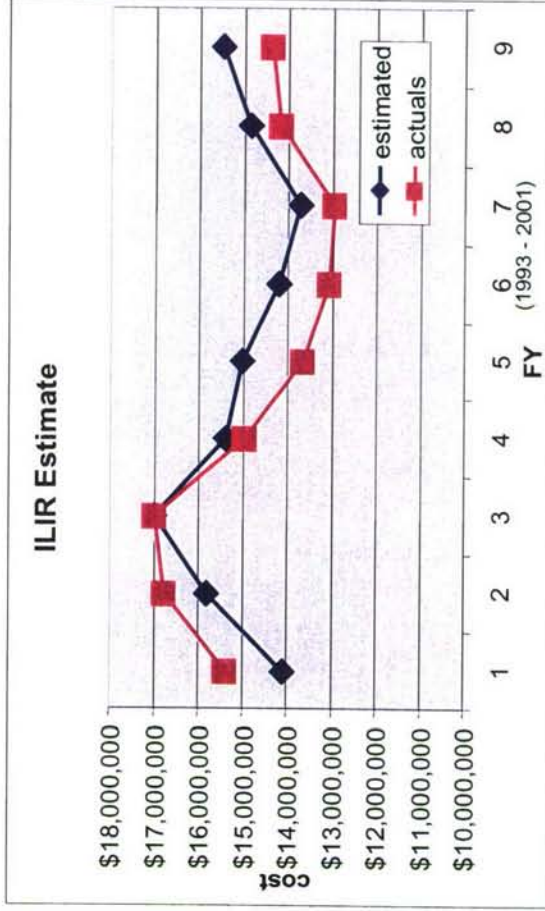
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# "Transitions"	No Data	38	35	41	33	38	44	49	50
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From Kavetsky brief to B Dept Offsite – Dec 2004.

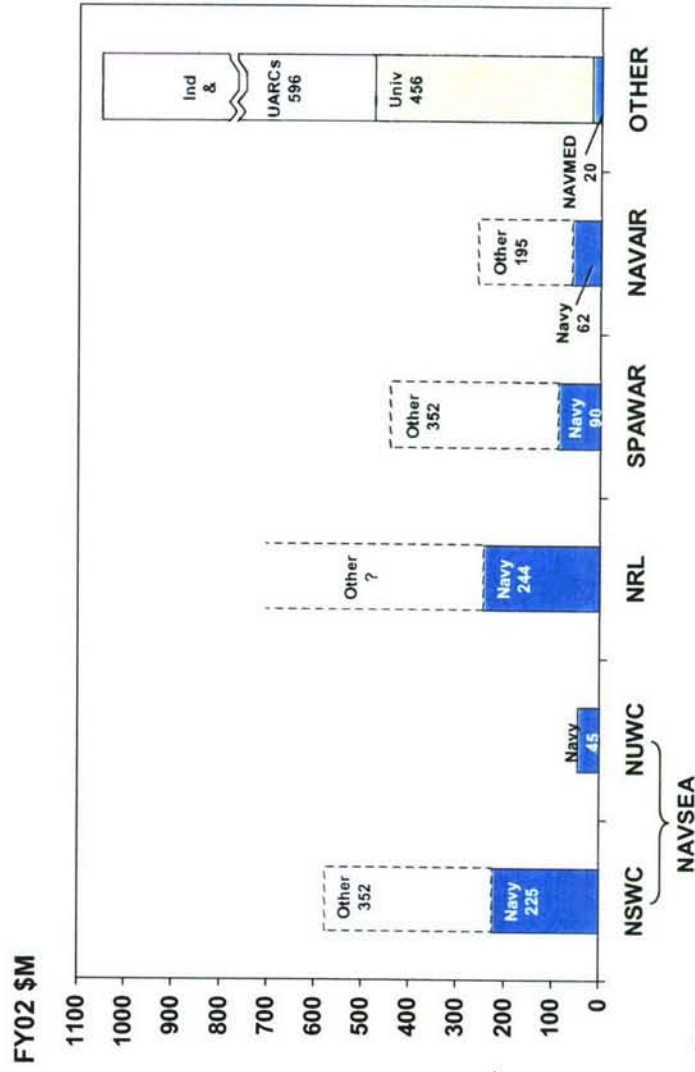
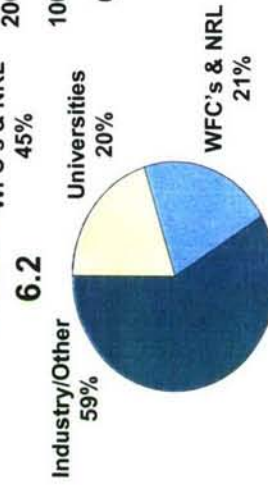
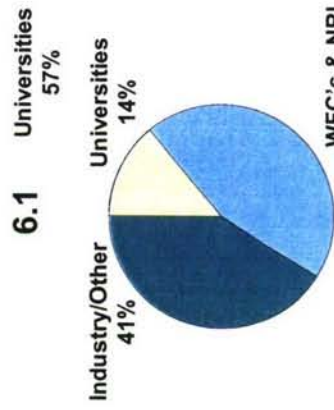
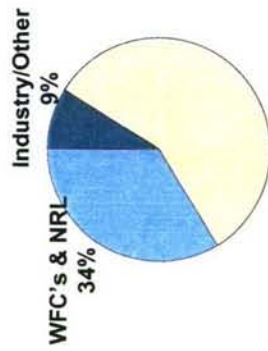
	1993	1994	1995	1996	1997	1998	1999	2000
Cpeople-est	\$14,109,312	\$15,836,436	\$17,023,882	\$15,415,704	\$15,054,480	\$14,231,808	\$13,755,744	\$14,861,340
actuals	\$15,400,000	\$16,800,000	\$17,000,000	\$15,000,000	\$13,700,000	\$13,100,000	\$13,000,000	\$14,200,000

Parameters	1993
Ng	181
Na	1
Np/a	1
Nproj	181
Ns	0.7
Ne	0
Ns&t	126.7
Pover	
n	0
WY	111,360
P%infra	0.1
Cpeople	\$14,109,312
Cinfra	\$0
Ctotal	\$14,109,312



12 April 2005

Distribution of S&T Funding FY02 Within the Naval Research Enterprise (NRE)



Source: FY 02 DDR&E Activities Report

12 April 2005

NAVY S&T REVITALIZATION

“CONCLUSION”

- S&T workforce will be broken within the current POM and incapable of pursuing transformational S&T

"The Navy has lowered its level of intellectual involvement in research and development and weakened its entire infrastructure, which at the end of WWII was the strongest in the world. For a service that sleeps on its weapons, this weakened institutional position in the world of science and engineering is dangerous. . .the Navy must bring the political, military and civilian scientist cultures into a mutually-supporting relationship."

- James Colvard

"The Bureaus Did Not Go On Forever. . ."

May 2002, Naval Institute Proceedings

12 April 2005

B-189

NAVY S&T REVITALIZATION

“CONCLUSION”

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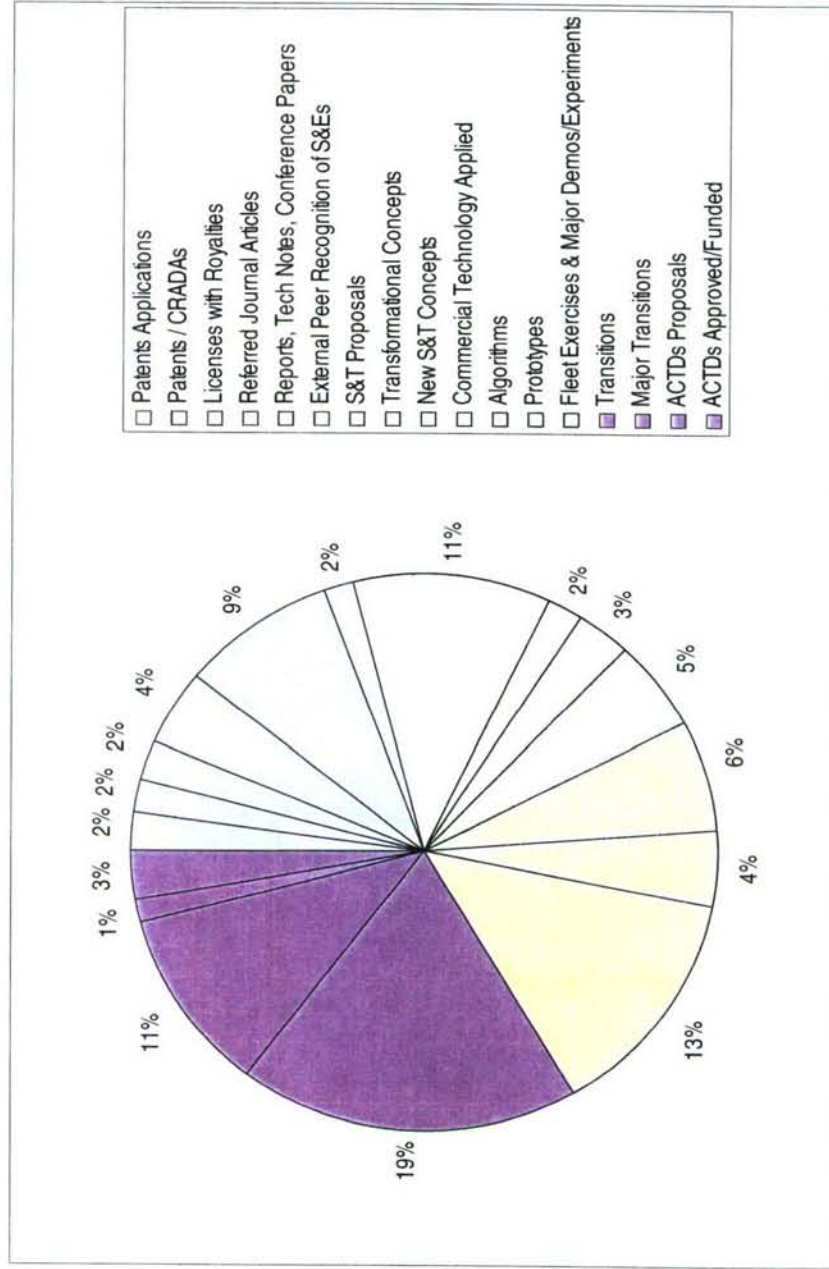
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- James Colvard

"The Bureaus Did Not Go On Forever. . ."
May 2002, Naval Institute Proceedings

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This is the problem in a nutshell. This is what we must declare and sell internal and external to the Navy. Kavetsky -2002



From Gary Kekelis – ROI Metrics

12 April 2005

Why S&T Metrics ?

A. Justify/defend the S&T Program

Metrics:

- a. Return-on-Investment (Frosch article)
- b. Costs Avoided (Crane example of microwave tubes)
- c. Warfighting Capabilities Achieved ("Fleet Transitions")
- d. Acquisition Funding Applied (example below)

B. Help Focus the S&T Program on Needs

Metrics:

- a. Alignment (JV2020, SP21, Grand Challenges...)
- b. Potential Payoff
- c. Technology Transition Agreements
- d. Set Quantitative Goals

C. Help manage the ongoing program and make adjustments

Metrics:

- a. Technical Quality Indicators (pubs/patents/awards/external reviews/other-funding-attracted (OFA))
- b. Progress Toward Goals (external/internal review ?)
- c. Continued Relevance to Warfighting Capabilities (external review ?)
- d. Vision process for new starts

Potential Metric: Acquisition Funding Applied to ONR Projects

Example 1: Directional Warhead System (DOS)

ONR Investment : \$6.5 M 1986 -1992

PMS-422 Investment: \$20+ M 1992 -1998 PE63609N (warhead, explosive, fuze now "on-the-shelf")

Example 2: Tomahawk Shipboard Mission Planning

ONR Investment: \$9.4 M 1989 -2000 (Quick Strike Planner)

NSWCDD Investment \$555K 1997-2000 (Quick Strike Planner)

PMA- 281 Investment \$ m M 1999 - 2004 (Launch Platform Mission Planner - May 2004 OPEVAL Certification)

We have studied metrics by program phase (planning, execution, result) and by Metric Categories (Activity, Output, Impact, Outcome). This may be just another way to shuffle the cards, but I thought I would capture it before those neurons discharge. Robin

Robin

12 April 2005

Age Distribution

6.1 and 6.2

Not current – FY-2000

40

35

30

25

20

15

10

5

0

#

Average Age: 42.75

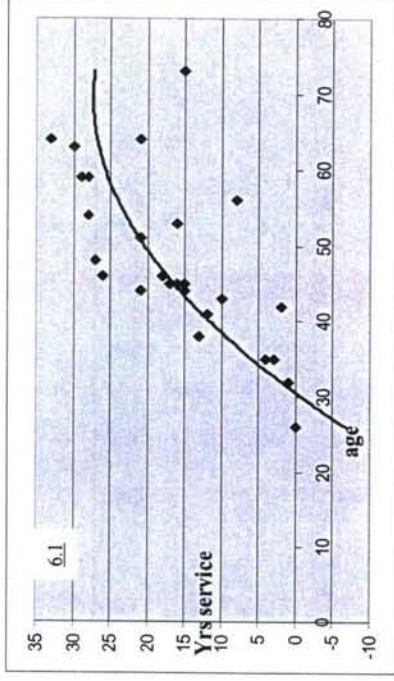
70

Age

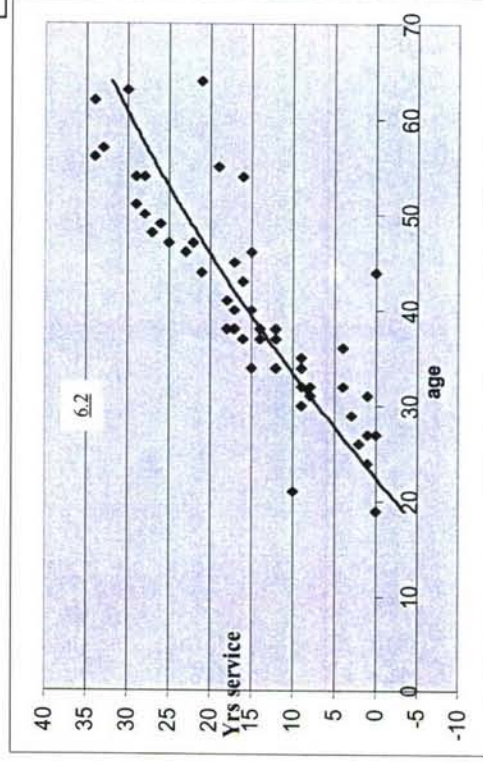
Data: 9/30/2000

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S&T Workforce FY-00 Data Age vs tenure



71% > 10 yrs experience



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